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ANATOMY AND PHYSIOLOGY

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INTRODUCTION

Before taking up the study of Anatomy and Physiology it is well to consider the definitions and terms which occur quite frequently in these subjects.

ANATOMY: is the science (or study) of the entire body structure. Human anatomy refers to the structure of the human body.

PHYSIOLOGY: is the science (or study) of the function of organs. Anatomy teaches us what organs a plant, or animal, or a body has, and how they are arranged with reference to one another. Physiology teaches us the uses to which these organs are put. Anatomy shows what an organ IS; physiology shows what an organ DOES.

In order for the Medical Department Soldier to intelligently perform his numerous duties in his connection with the sick and wounded it is desirable and necessary that he should understand something of the structure of the human body and the functions of its various organs.

DEFINITIONS

CELL: A cell is the SIMPLEST UNIT from which all living materials are built up. Each cell has an (a) OUTER MEMBRANE, (b) CYTOPLASM, and (c) a NUCLEUS.

TISSUE: A tissue is a GROUP OF CELLS similar in origin, structure and function, together with a substance between the cells which holds them together.

ORGAN: An organ is a group of tissues united together in ONE UNIT for the performance of a SPECIAL FUNCTION OR WORK.

A SYSTEM: A system is a group of organs associated together to perform a special function. NINE SYSTEMS are found in the Human Body. Their names with the functions of each are briefly expressed as follows:

1. SKELETAL SYSTEM: Whose function is the support of the body as a whole.
2. RESPIRATORY (or breathing) SYSTEM: To move air in and out of the body so as to provide OXYGEN and discharge CARBON DIOXIDE.

3. ALIMENTARY SYSTEM: (or Digestive System) — To receive, digest (break down) and absorb the food which is to be used by the body cells.

4. MUSCULAR SYSTEM: Produces the Contraction of variout body parts which results in motion.

5. VASCULAR (or Circulatory) SYSTEM: Distributes the body fluids (blood, plasma, lymph) to the cells of the body.

6. EXCRETORY SYSTEM: Functions so as to eliminate the waste products of the body that result from cell activity.

7. NERVOUS SYSTEM: Controls and insures coordination in the functions of all the systems of the body. Contains the centers for all the SENSATIONS, INTELLIGENCE and THOUGHTS, etc., that we recognize as the highest functions of life.

8. REPRODUCTIVE SYSTEM: Insures the continuance of the race by the production of offspring.

9. ENDOCRINE (or Ductless Gland) SYSTEM: Is composed of certain ductless glands, whose function is to secrete (or produce) certain chemical substances called HORMONES directly into the blood-stream which have to do with the GROWTH and DEVELOPMENT of the body.

It is important to remember that these systems are closely related to, and dependent on, each other. The most perfect skeleton is not capable of support unless assisted by the MUSCULAR and NERVOUS SYSTEMS. Any interference with the CIRCULATORY SYSTEM will result in efficiency of the EXCRETORY SYSTEM, etc.

Certain terms or words are frequently used in Anatomy to indicate regions or areas of the body. The Medical Department Soldier should learn these terms and what they mean, in order to better understand his co-workers when discussing injuries, wounds, and other abnormal conditions.

ANATOMICAL POSITION: Is that one in which an individual stands erect with the arms at the sides and the palms forward.

DORSAL: Refers to back where the Spinal (or Vertebrae) column is located. VENTRAL means the opposite, or belly side.

ANTERIOR: Refers to the part of the body which is forward when in normal forward motion.

POSTERIOR:	Refers to the back of the body.
SUPERIOR:	Refers to the region of the body which is uppermost when in the standing position. INFERIOR means the opposite end.
INTERNAL:	Means in the interior of the body mass. EXTERIOR means the opposite.
PROXIMAL:	Means nearer to the SOURCE, or point of ATTACHMENT.
DISTAL:	Means farther from the SOURCE, or point of ATTACHMENT.
	(These terms are used only in connection with the extremities or limbs).
MEDIAL:	Means toward the mid-line of the body.
LATERAL:	Means farther from the mid-line of the body.
PARIETAL:	Refers to the walls of a cavity.
VISCERAL:	Refers to the VISCUS or ORGAN located within that cavity.

VARIETIES OF TISSUES

Tissues in the Adult human body are usually classified into six main groups, viz:

1. EPITHELIAL tissues.
2. CONNECTIVE tissues.
3. MUSCULAR tissues.
4. BLOOD and LYMPH - (are "fluid" tissues).
5. NERVOUS tissue.
6. OSSEOUS (or Bone) tissues.

Examples of types or groups of body tissues:

1. EPITHELIAL tissue makes up the outside layer of the SKIN, the LINING of the DIGESTIVE, CIRCULATORY, EXCRETORY, RESPIRATORY SYSTEMS; this tissue also lines the inside walls of the BLOOD VESSELS and SEROUS CAVITIES.

   Other epithelial tissue cells such as those lining the MOUTH, NOSE, TRACHEA, etc., can produce a substance known as MUCOUS. The layers of tissue where these cells are located are known as MUCOUS MEMBRANES.

2. CONNECTIVE TISSUE is the supporting tissue of the body. Just as cement or mortar holds the building bricks in a building, so does the connective tissue serve to hold the various body parts and organs in place. This type of tissue has a wide distribution in the body.

3. MUSCULAR TISSUE is the tissue of which muscles are formed. It is composed of specialized cells which have become elongated and modified to form thread-like fibers held together by strong connective tissue. Muscle tissue has the property of being IRRITABLE (responds to stimulation from nerves), CONTRACTILE (shortens its length), TONIC (has a firm steady pull on ligaments, etc.), and EXTENSIBLE (can extend its length if needed).

   CARDIAC MUSCLE (Heart Muscle) is the most specialized of all muscle tissue because of the types of work this particular muscle has to perform. This will be discussed in the chapter on the Circulatory System.

4. BLOOD and LYMPH may be considered as tissues consisting of free cells floating in a fluid base, both of which are constantly being circulated through the body, within the blood vessels.

5. NERVOUS TISSUE is composed of nerve cells, nerve fibers, and a supportive framework of moderately strong connective tissue. This is the most highly specialized tissue in the entire human body, and will be discussed more fully in the chapter devoted to The Nervous System and Special Senses.

6. OSSEOUS (Bone) TISSUE is composed of tissue in which calcium salts have been deposited forming a rigid type of substance known as Bone.

CHAPTER I

THE SKIN

Normal skin is made up of two layers: (1) THE EPIDERMIS, or cuticle; (2) THE DERMIS, or the true skin. The dermis, or deeper layer of the two, contains all the blood vessels, nerve endings and glands with which the skin is abundantly supplied. The upper layer, or epidermis, becomes modified to form such extra structures as HAIR and NAILS.

The Function of the Skin as a whole:--

1. Protection against BACTERIA, undue evaporation, INJURY.

2. Receives all the nerve ends which result in the sensations of heat, cold, sharp and dull pain, and position sense.

3. Excretory function. The skin assists the body in excreting certain waste products along with those excreted by the INTESTINAL TRACT and by the EXCRETORY SYSTEM.

4. Temperature Regulator. The skin assists the body in maintaining a normal temperature. When the outside temperature is below normal, the blood vessels or capillaries in the skin contract, thus tending to hold within the body the normal body heat. When the atmospheric temperature is unduly warm or hot, the skin assists the body in cooling by the production of perspiration. Normally, about one quart of this fluid is excreted daily, but that amount varies widely with the atmospheric temperature and the humidity, and the amount of exercise taken. PERSPIRATION, or sweat, consists mainly of WATER, with small amounts of SALT, FATTY ACIDS, UREA and CARBON DIOXIDE.

Some of the commoner conditions which affect the skin as seen in the Army may be enumerated as follows:

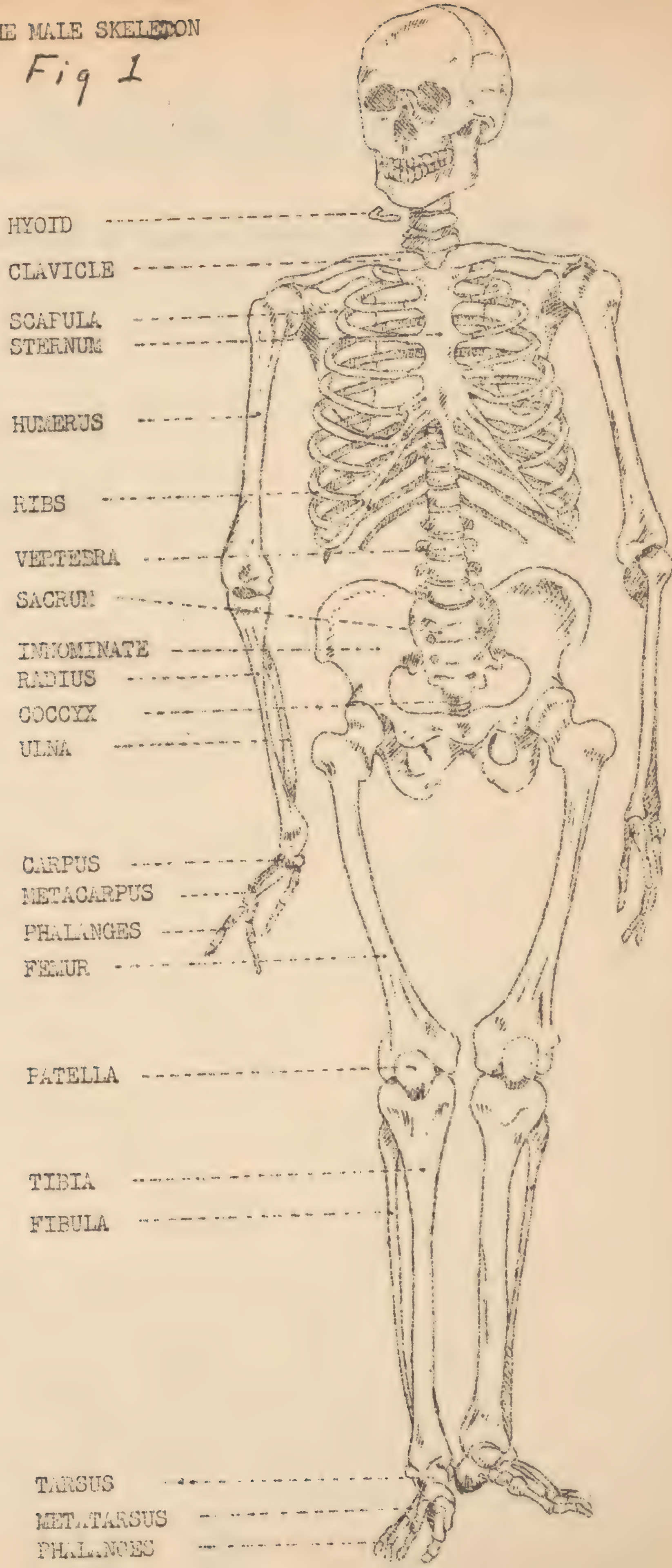
1. ACNE (or pimples).
2. BLACKHEADS (or comedones).
3. BOILS, (or abscesses).
4. CARBUNCLES.
5. PEDICULOSIS, or infestation of the skin with LICE.
6. SCABIES, a condition involving the skin caused by the itch mite.
7. ATHLETE'S FOOT, a condition of the feet resulting from an infection by a parasitic FUNGUS.
8. DERMATITIS VENENATA. This is an inflammatory condition of the skin caused by some external irritation to which the person may be sensitive. Examples are POISON OAK and POISON IVY.

Last, but not least, should be mentioned the skin lesions caused by SECONDARY SYPHILIS. These skin lesions are often hard to differentiate from other conditions which may be purely innocent.

For the prevention and care of these conditions, the student should refer to his notes in the Hygiene and Sanitation text.

THE MALE SKELETON

Fig 1



CHAPTER II

THE SKELETAL SYSTEM

A. DEFINITION: The skeletal system may be defined as a group of bones which form a supporting FRAMEWORK of the body.

B. The NUMBER of bones in the skeletal system. There are about 206 bones in the adult body, not including the thirty-two normal teeth.

C. FUNCTION: The skeletal system has as its function the following:

1. It serves as the rigid framework of the entire body.
2. It affords places or sites for attachment of the many muscles of the body.
3. It PROTECTS the more delicate parts of the body, viz:-

    a. The brain.
    b. The eyes.
    c. The Spinal Cord.
    d. The organs in the THORACIC cavity, or chest cavity.
    e. The organs in the ABDOMINAL cavity.
    f. The organs in the PELVIC cavity.

D. The SKELETAL SYSTEM assists in the formation of the CELLS which are found in the BLOOD, namely: The RED BLOOD CELLS, the WHITE BLOOD CELLS, and the PLATELETS. These will be discussed under the chapter on the CIRCULATORY SYSTEM. BONES are of certain types, according to their <u>shape</u>:--

1. LONG BONES, such as those found in the extremities.
2. SHORT BONES, such as those found in the wrist and the ankle.
3. FLAT BONES, such as those which occur in the skull and in the ribs.
4. IRREGULAR BONES. Include all those not classified above; in other words, those of the vertebral column.
5. SESAMOID BONES, or small bones found lying in soft tissue such as the "Knee Cap" -- their function is protective.

    a. Patella.

E. STRUCTURE of an adult bone. We take a typical bone as an example. A bone such as the FEMUR or the HUMERUS, for instance, is completely covered around its outside surface with a fibrous membrane known as a PERIOSTEUM. This PERIOSTEUM has running in it small blood vessels and numerous nerves. The blood vessels serve to nourish the outside layer of the bone. In addition to the nourishment brought to the bone in this manner, there are arteries which enter

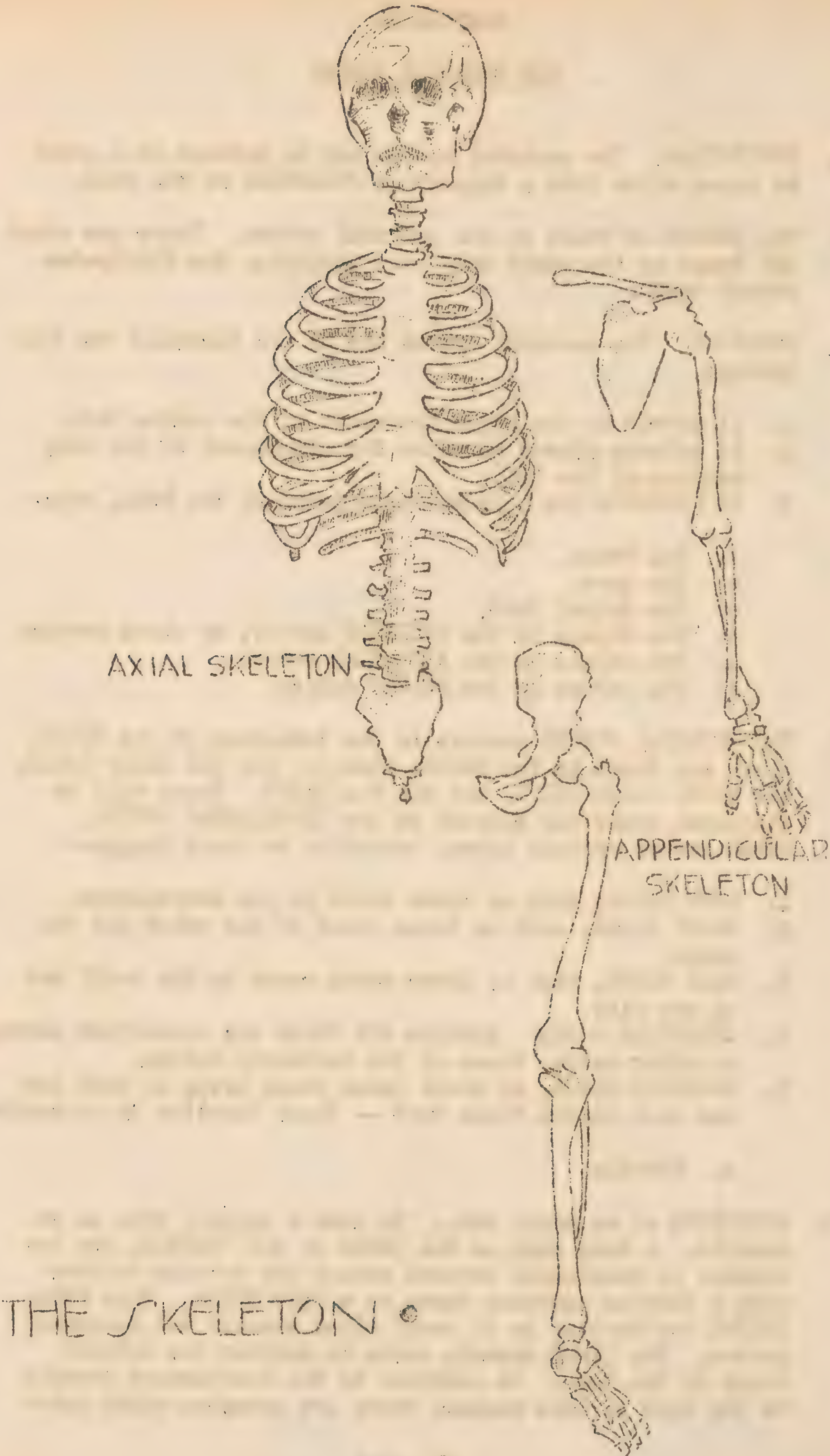


FIG. 2.

a long bone, one at either END. After the blood gains admission to the bone itself, it flows along a cavity in the inside of the bone known as the MEDULLARY CAVITY, wherein the bone marrow is located. It is the bone marrow that is extremely important as a BLOOD-FORMING ORGAN.

VARIOUS SKELETAL PARTS (See Figure #2).

A. THE AXIAL SKELETON, which is composed of (1) the SKULL, (2) the VERTEBRAE of the SPINAL COLUMN, and (3) the RIBS, of which there are ten TRUE pairs and two FALSE pairs.

B. THE APPENDICULAR SKELETON: composed of the bones of the Extremities and their related "girdles".

1. THE SKULL or CRANIUM: Is composed of 8 bones which dove-tail together in the young adult to form a SOLID BONE BOX which encloses the Brain. These bones which are separate bones in the child are:-

Occipital	(1)	Temporal	(2)
Parietal	(2)	Ethmoid	(1)
Frontal	(1)	Sphenoid	(1)

The FACIAL BONES also included in the Skull are;

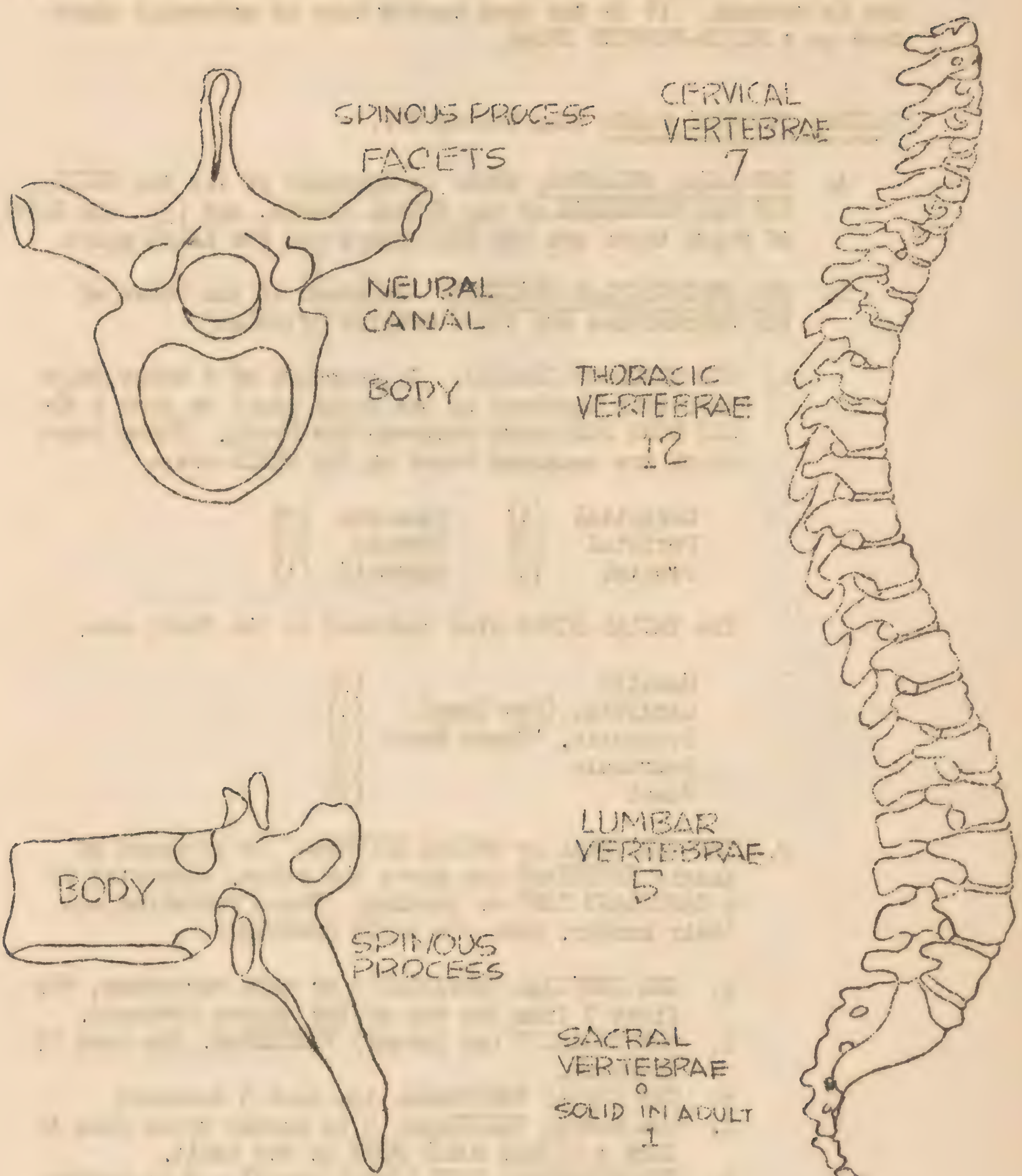
Maxilla	(2)
Mandible, (Jaw Bone)	(1)
Zygomatic, "Cheek Bone"	(2)
Lacrimals	(2)
Nasal	(2)

2. THE VERTEBRAL or SPINAL COLUMN:- Is composed of single VERTEBRAE one above the other, separated by a CARTILAGE DISC or cushion. These vertebrae and their number, from the skull downward:

a. THE CERVICAL VERTEBRAE - or neck vertebrae, the first 7 from the top of the column downward.
b. THE THORACIC (or Dorsal) VERTEBRAE, the next 12 downward.
c. THE LUMBAR VERTEBRAE, the next 5 downward.
d. THE SACRAL VERTEBRAE, 5 in number which fuse to form a SINGLE SOLID BONE in the adult.
e. THE COCCYGEAL BONE ("tail bone") - 4 in number which also fuse to form 1 bone in the adult.

Therefore there are 33 vertebrae in the CHILD'S Spinal Column and 26 vertebrae in the ADULT Spinal Column (See Figure #3C).

3. THE RIBS: There are 12 pair of ribs, the upper 10



COLUMNA VERTEBRALIS

FIG 3

being TRUE RIBS and the lower 2 pairs being the FALSE or "Floating Ribs". The true ribs are attached in front to the STERNUM or "Breast-bone". The false ribs are not attached in front, thus they are called "floating ribs."

B. THE APPENDICULAR SKELETON, which is composed of the bones which go to make up the four extremities, and their related "girdles".

1. THE UPPER EXTREMITY:-

   a. THE SHOULDER GIRDLE, made up of the scapula ("Shoulder Blade") and the CLAVICLE (or "Collar Bone"). The SCAPULA is attached to the spinal column by heavy muscle bundles. The CLAVICLE is attached to the STERNUM in front, and the scapula at the shoulder joint.

   b. The HUMERUS or the single large bone in the arm. The upper end of the HUMERUS fits into the GLENOID CAVITY of the SCAPULA to form the SHOULDER JOINT.

   c. The RADIUS, and the ULNA, or the two bones of the forearm.

   d. The CARPAL BONES (8) form the Wrist Joint.

   e. The METACARPAL BONES (5) form the Hand.

   f. The PHALANGES form the fingers (3 in each finger).

2. THE LOWER EXTREMITY:-

   a. The PELVIC GIRDLE formed by the ILIUM BONES (2).

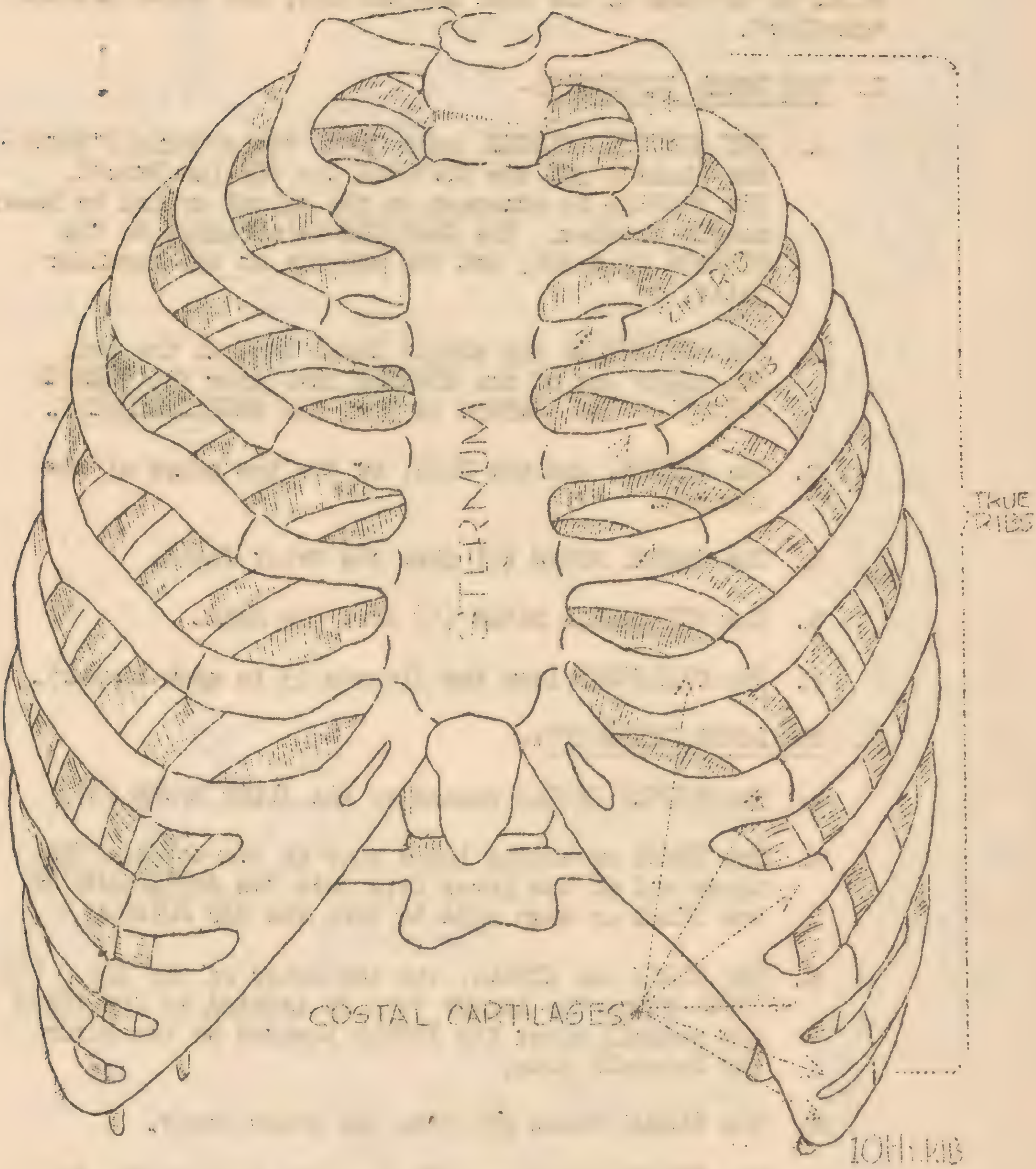
   b. The FEMUR or single large bone of the thigh. The upper end of the femur fits into the ACETABULUM of the Ilium on each side to form the HIP JOINT.

   c. The TIBIA and FIBULA, the two bones of the leg. The TIBIA being the larger bone is located on the inner (or medial) side; the FIBULA located on the outer (or lateral) side.

   d. The TARSAL Bones (8) form the ankle bones.

   e. The METATARSAL Bones (5) form the arch of the foot.

   f. The PHALANGES (3 in each toe) form the Toe Bones.



THE BONY THORAX, STERNUM AND RIBS

FIG. 4

THE BONY THORAX

The BONY THORAX or RIB CAGE is shaped like a cone with the small end pointed upwards. It is made of the (1) STERNUM in front, (2) The COSTAL CARTILAGES and RIBS on the sides, and (3) The RIBS and VERTEBRAE or Spinal Column behind. (See Fig. #4).

THE SHOULDER GIRDLE and UPPER EXTREMITY are attached to this Thoracic Cage by heavy bundles of muscles. The HEART, GREAT VESSELS, and the LUNGS are enclosed within this protective Rib Cage (or Thoracic Cage).

THE PELVIC GIRDLE (PELVIS)

The female pelvis as compared with the male is more shallow, wider than the male, with a larger inlet and outlet. The COCCYX, or tail bone, is more movable in the female, and the ligaments which bind the SYMPHYSIS PUBIS together in front are more relaxed than the male. On the other hand, the male pelvis is made up of bone which is more DENSE and is HEAVIER than the bone found in the female pelvis. The architecture of the female pelvis is principally designed for the process of child-bearing, whereas, the male pelvis is designed for strength and power.

THE JOINTS (ARTICULATIONS)

Joints are the unions by which the various bones of the skeleton come together.

There are TWO principal types of JOINTS:

1. The MOVABLE.
2. The IMMOVABLE.

An example of an IMMOVABLE JOINT is the skull, where the bones are dove-tailed together. The HIP and SHOULDER, on the other hand, are examples of FREELY-MOVABLE JOINTS. The articulations or union of the pubic bone and the pelvis, and the lower ends of the tibia and fibula are examples of partly movable joints. The opposing ends of two bones entering into a joint are covered with a substance known as CARTILAGE. The bones entering into a joint are held together by strong bands of fibrous tissue called LIGAMENTS, which pass from one bone to the other on every side of the joint, and form a CAPSULE, which is the external boundary of the joint cavity. This fibrous capsule is lined with a membrane known as a SYNOVIAL FLUID, that is retained in the cavity and serves to lubricate the joints. On a basis of possible movement, all JOINTS or ARTICULATIONS are classified as follows:

1. Those which are IMMOVABLE. Also called "fixed joints."
2. Those which are SLIGHTLY MOVABLE, or "half joints".
3. Those which are FREELY MOVABLE, or "true joints."

Some types of FREELY MOVABLE JOINTS are:

1. GLIDING JOINTS. Permits a sliding type of movement. An example of this type of joint would be the articulations between the vertebrae of the spinal column.

2. BALL-AND-SOCKET JOINTS. Permits angular movement, circumduction, and rotation. An example of this type of joint would be the shoulder and hip joint.

3. HINGE JOINT. Permits movement on a single axis. An example of this type of joint would be the elbow joints or the joints between the fingers, or between the fingers and the hands.

Special movements of the forearm and hand.

1. SUPINATION. This is the movement which results in turning the forearm into the SUPINE position. In this position the palm would be straight up.

2. PRONATION. This is the movement which is opposite to supination. This movement turns the back of the hands forward or up. It is associated with crossing the radius over the ulna.

SOME INJURIES AND DISEASES OF BONES AND JOINTS.

1. FRACTURES. See first aid lectures and notes.
2. DISLOCATIONS. See first aid lectures and notes.
3. SPRAINS. See first aid lectures and notes.
4. FLAT FOOT. This condition is due to the stretching of ligaments and muscles that keep the small bones of the foot in their proper relation to one another.

   Cause:-

   Usually by standing over long periods of time with the weight borne on the wrong part of the foot. May be avoided by wearing PROPERLY FITTED SHOES and standing with the toes turned in somewhat and the weight placed toward the outer side of the foot. This condition is difficult to remedy after it has once taken place.

5. RICKETTS. This is the disease of bones occurring in infancy or early childhood due to lack of vitamin D in the diet, or inadequate calcium intake. In this condition bone formation occurs in a disorderly fashion. Some portions of the bone become softened, due to a lack of LIME (or calcium salts). Then the PULL of the muscles or WEIGHT on that bone tend to cause the bone to bend out of shape. Then, as the child grows older, this bent bone usually becomes hard, and the deformity becomes permanent. Common deformities due to ricketts are:

   (1) Pidgeon Breast.
   (2) Bow legs.

6. OSTEOMYELITIS, or an infection of the bone which produces pus, draining sinuses, and a long period of disability usually follows.

7. ARTHRITIS. A disease affecting the joints usually of older people. This disease is of several kinds, some of which may become very chronic and lead to permanent disability and deformity of the joints involved.

8. TUBERCULOSIS may occur in bones or in joints and is difficult to cure, once established.

9. BONE TUMORS.

SUMMARY

The skeletal system is made up of a group of bones, numbering about 206 in the adult, and the unions between these bones. Its function is to form a SUPPORTING FRAMEWORK for the body, to serve as the ATTACHMENT of the MUSCLES, to protect the more delicate parts of the body, and is concerned with the FORMATION of BLOOD CELLS.

Bones are made up of microscopic cells, just as are other tissues of the body, but bone cells become hardened because lime salts (calcium) are deposited in these cells early in life.

The skeleton is made up of the BONES of the SKULL; the BONES of the TRUNK (include 33 vertebrae, the sternum, and the 24 ribs); the BONES of the UPPER and LOWER EXTREMITIES.

Bones are held together by LIGAMENTS and the points of contact of bones are called ARTICULATIONS or JOINTS.

ARTICULATIONS may be divided into different types, and the movements possible at any one joint are determined by the <u>shape</u> of that joint.

CHAPTER III

MUSCULAR TISSUE

One of the important functions of the human body is motion. Under this heading is included many types of movements, i.e., the ability to move from place to place, the movements of breathing, the beating of the heart, the activities of the stomach, etc. Varied as these movements seem to be they are all dependent upon the forcible contraction of muscular tissue. This tissue forms the bulk of all the muscles which are attached to the skeleton, and which by contracting bring about changes in the form and position of nearly all parts of the body.

Muscular tissue also forms the walls of such organs as the heart, stomach and intestines. Contractions of this tissue decrease the capacity of these organs, while relaxation increases it. Consequently, muscular tissue is classed as a motor tissue, but the activities of the muscular system are dependent on the skeleton and the nervous system. In fact, the skeleton, the muscular system, and the nervous system are correlated parts, the degree of usefulness of any one of them depending on the development and proper functioning of the others.

The appearance of human muscular tissue is roughly comparable to the lean of butcher's meat. It constitutes from 40 to 50 percent of the body weight. The characteristics that enable it to perform the function of motion are irritability, contractility, extensibility and elasticity.

Irritability may be defined as the power of receiving and responding to stimuli. All cells possess this property; nervous ciliated epithelial cells, and the cells of muscular tissue in a marked degree. The response of any tissue to stimulation is to perform its special function, and in the case of muscular tissue this response takes the form of contraction.

Contractility is the power which enables muscles to change their shape so as to become shorter and thicker. It is possessed to some degree by all living protoplasm, but is highly developed in muscular tissue.

Extensibility of a living muscle means that it can be stretched or extended, and elasticity means that it readily returns to its original form. Normally, the skeletal muscles are in a condition of slight tension, being stretched from bone to bone. This condition is of importance in two ways: (1) smoothness of movement is dependent upon it; (2) a stretched muscle will contract more quickly than one that is relaxed.

Like every other tissue muscular tissue is composed of cells and intercellular substance, with this difference, that the cells become elongated. The intercellular substance consists of a small amount of cement, which helps to hold the cells together, or to the framework of reticular tissue in which they are embedded.

CLASSIFICATION

Muscle cells are of three distinct kinds, and we therefore distinguish three varieties of muscular tissue:-

1. Striated or cross-striped.
2. Non-striated or plain.
3. Cardiac.

Striated or cross-striped muscular tissue.--This tissue is called striated because it is distinctly marked by striae, or parallel cross stripes. It is also called skeletal because it forms the muscles which are attached to the skeleton, and voluntary because it is nearly always under the control of the will. It is composed of long slender cells, measuring on an average of 1/500 inch (0.05 mm.) in diameter, but having a length of an inch or more.

Each cell consists of three distinct elements:-

(1) Contractile substance, forming the center and making up most of the bulk of the cell.

(2) Nuclei, which lie scattered upon the surface of the contractile substance.

(3) The sarcolemma, a thin, structureless tube which tightly encloses the contractile substance and the nuclei.

As each cell contains a number of nuclei, we may regard it as a multinuclear cell of elongated form. The muscle cells lie closely packed, their ends lapping over onto adjacent cells and forming bundles. Delicate reticular tissue carrying blood-vessels and nerves penetrates between the cells, surrounds the small bundles and groups them into larger bundles. Reticular tissue also surrounds the larger bundles and forms a covering for the whole muscle. Thus it will be seen that reticular tissue forms a supporting framework for muscular tissue.

SKELETAL MUSCLES.--The muscles are separate organs, each muscle having its own sheath of connective tissue, called epimysium. They vary in size from a fraction of an inch to nearly twenty-four inches (60 cm.) and are very diverse in form. In the trunk the muscles are broad, flattened, and expanded, forming the walls of the cavities which they enclose. In the limbs they are of considerable length, forming more or less elongated straps. A typical muscle is described as consisting of a body and two extremities. The body is the red contracting part, and the extremities are the ends where they are attached.

Attachment of the muscles to the skeleton.--Muscles are attached to the bones, cartilages, ligaments, and skin in various

ways, the most common mode of attachment being by means of tendons. The muscle fibers converge as they approach their tendinous extremities, and gradually blend with the fibers of the tendons, the tendons in their turn inserting their fibers into the bones. Where one muscle connects with another, each muscle ends in expanded form in a flat, fibrous membrane called an aponeurosis. Again, in some cases, the muscles are connected with the bones, cartilages, and skin, without the intervention of tendons or aponeuroses.

Annular ligaments.—In the vicinity of the wrist and ankle, parts of the deep fascia become blended into tight transverse bands, which serve to hold the tendons close to the bones. These bands are called annular ligaments.

Origin and insertion.—It is customary to speak of the attachments of the opposite ends of muscles under the names of origin and insertion, the first term origin being usually applied to the more fixed attachment; the second term insertion being applied to the more movable attachment. The origin is, however, absolutely fixed in only a very small number of muscles, such as those of the face, which are attached by one end to the bone, and by the other to the movable skin.

NON-STRIATED OR PLAIN MUSCULAR TISSUE.—This tissue is called plain or non-striated because it does not exhibit parallel transverse striae or stripes. It is also called visceral because it constitutes a large portion of the substance of many of the viscera, and involuntary because it is usually withdrawn from the control of the will. It is composed of elongated cells, each having a thin cell wall, no sarcolemma, and containing a single elongated nucleus.

CARDIAC MUSCULAR TISSUE.—This variety of muscular tissue is found only in the heart substance. It is involuntary, but is striated, though not as distinctly as skeletal muscle. It is made up of cells which are short, contain just one nucleus, and no sarcolemma. The cells are grouped in bundles which are nearly square, and fine fibrils from each cell help to hold the bundles together. The bundles are mainly held by reticular tissue, which forms a supporting framework in the heart, just as it does in skeletal and visceral muscle.

STIMULI.—This term is used to describe influences which stimulate muscle cells. They may be chemical, mechanical, thermal, electrical or nervous.

NERVES.—Muscular tissue is well supplied with nerves. Certain nerves convey impulses from the central nervous system to the muscles and control their contraction. These are called motor nerves. Certain other nerves have sensory end organs in the muscles. These convey to the central nervous system the state of contraction of the muscle and hence are called sensory nerves. By means of these sets of nerves coordinated activities of groups of muscles are brought about.

TONE.—The constant and insensible tendency to contract which exists under normal conditions is described as tone. It is really a mild, sustained contraction, and though it may vary in degree, it is rarely absent altogether.

The tone of the skeletal muscles is due to stimuli from the central nervous system that are not intense enough to cause motion but gives them a certain firmness and maintains a slight steady pull upon their attachments. In fractures the over-riding of the broken ends of a bone is often due to the contraction of the muscle that is the result of its tonicity.

The tone of visceral muscles is partly due to substances in the blood, i.e., sodium, potassium and calcium salts, and secretions from the ductless glands as well as stimuli from the nervous system. It prevents excessive distension of hollow organs by their contents.

TETANUS.—When a muscle receives a series of repeated stimuli so rapidly that there are no periods of relaxation, it remains in a condition of contraction as long as the stimuli are sent in, or until it loses its irritability from fatigue. A contraction of this kind is described as a compound contraction or tetanus.

BLOOD-SUPPLY AND SOURCE OF ENERGY.—All varieties of muscular tissue are well supplied with blood-vessels which are supported and carried by the connective tissue. They do not penetrate into the cells, but each cell is bathed in lymph which exudes from the blood-vessels. One of the substances brought by the blood to the muscles is glucose which is stored in the cells as glycogen. This represents chemical energy, which stimuli may transform into mechanical energy. Muscles may be compared to engines capable of converting chemical energy into mechanical. The transformation of energy which accompanies muscular activity is associated with the oxidation of glycogen and perhaps fat, and the formation of waste compounds, i.e., carbon dioxide water, lactic and sarcolactic acid. These waste compounds must be eliminated, and except in cases of prolonged contractions, the system is able to get rid of them readily.

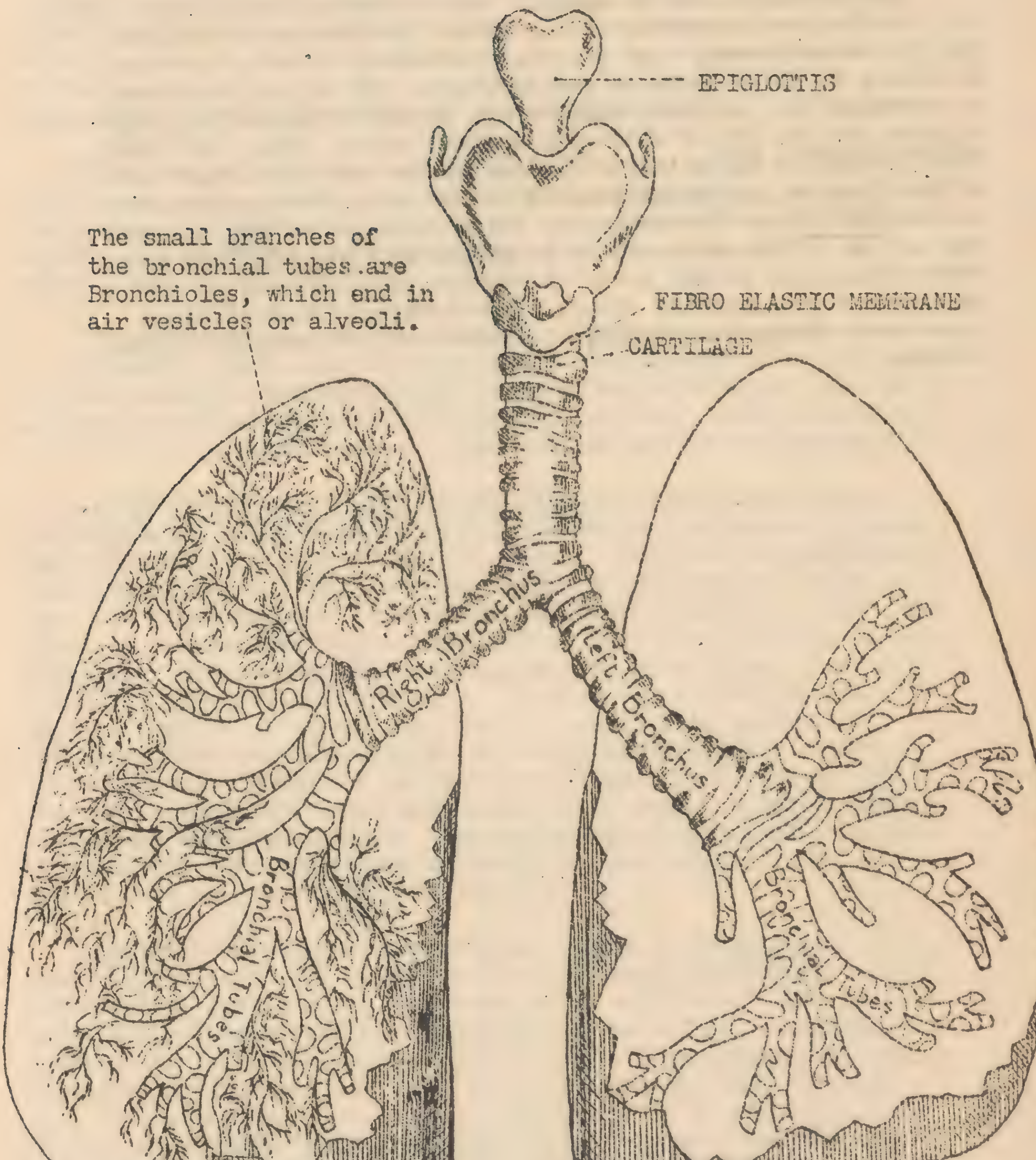
Fatigue.—Prolonged contractions result in fatigue, and this means two things: (1) an accumulation of waste substances, (carbon doixide, lactic acid, and sarcolactic acid) which acts as poisons, (2) a loss of nutrient material. A period of rest furnishes opportunity for the blood to carry these fatigue poisons to the excretory organs; and nutritive material from the digestive organs to the muscles. In cases of extreme fatigue resulting from prolonged overwork the fatigue poisons circulate in the blood and lessen the irritability of muscular tissue so that it fails to respond to stimuli. It has been demonstrated that the injection of the blood of a fatigued animal into a rested one will promptly bring on signs of fatigue.

FUNCTIONALLY IMPORTANT SKELETAL MUSCLES.

The skeletal muscles are usually called by their Latin names, as they are often descriptive of some distinctive characteristic, such as their form, size, attachment, location, function, etc.

The majority occur in pairs. Only a few are single, and they are located about the median line. Muscles may be classified in several ways. The most helpful way is to classify them according to their location and function. It is most important to remember that skeletal muscles are usually arranged in antagonistic groups, one of which opposes the other. Thus, the muscles located on the anterior surface of the arm and forearm are called flexors, and those located on the posterior surface are called extensors. The action of the flexors is to bend the arms, the action of the extensors is to extend or straighten the arms. When stimulated, either group of muscles must overcome the resistance of the opposing group. Therefore, contraction takes place more slowly and evenly, and smoothness of movement is the result.

Fig. 5



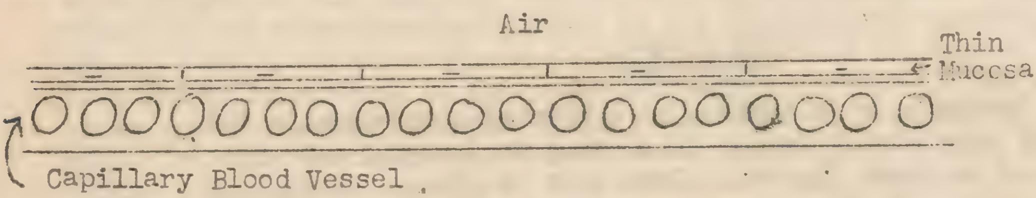
The Bronchioles are like ferns in appearance.

CHAPTER IV.

THE RESPIRATORY SYSTEM

All living things require oxygen for their vital processes. The normal course of all the chemical changes in the tissue cells is dependent upon oxygen, hence the need of a continual supply. One of the end-products of the same chemical changes is carbon dioxide, hence the need for continual elimination. In unicellular animals the intake of oxygen and the output of carbon dioxide occur at the surface of the cell. As organisms increase in size some form of apparatus is developed whose function consists in bringing air or oxygen-laden water to all the cells of even the most complex organisms. In man the circulating blood is brought in contact with the air in the lungs, where it takes up oxygen and gives up carbon dioxide, and later with the cells in the tissues where it gives up oxygen and takes up carbon dioxide.

This exchange of gases is known as respiration and is dependent upon the proper functioning of certain organs which we group together and call a RESPIRATORY SYSTEM. The essentials of a respiratory system consist of a moist and permeable membrane, with a moving stream of blood containing a high percent



ESSENTIALS OF A RESPIRATORY SYSTEM

age of carbon dioxide on one side, and air or fluid containing a high percentage of oxygen on the other. In mose aquatic animals the respiratory organs are external, in the form of gills; in terrestrial, or air-breathing animals, the respiratory organs are situated internally in the form of lungs, and are placed in communication with the nose and mouth by means of the bronchi, trachea, and larynx.

Under this heading we group the organs which are concerned in the process of respiration. In man they are as follows:-- See Figure #5.

1. Larynx. 3. Bronchi.
2. Trachea. 4. Lungs.

THE LARYNX

The larynx, or organ of voice, is placed in the upper and front part of the neck, between the base of the tongue, and the top of the trachea. Above and behind lies the pharynx, which opens into the esophagus, or gullet, and on either side of it lie

the great vessels of the neck. The larynx is broad above and shaped somewhat like a triangular box, with flat sides and prominent ridge in front. Below it is narrow and rounded where it blends with the trachea. It is made up of nine pieces of fibro-cartilage, united by elastic ligaments, and moved by numerous muscles.

THE GLOTTIS.--Across the middle of the larynx is a transverse partition, formed by two folds of the lining mucous membrane, stretching from side to side, but not quite meeting in the middle line. They thus leave in the middle line a chink, or slit, running from front to back, called the glottis, which is the narrowest segment of the air passage. The glottis is protected by the leaf-shaped lid of fibro-cartilage, called the epiglottis, which shuts down upon the opening during the passage of food or other matter into the esophagus.

THE VOCAL CORDS.--Embedded in the mucous membrane at the edges of the slit are fibrous and elastic ligaments, which strengthen the edges of the glottis and give them elasticity. These ligamentous bands, covered with mucous membrane, are firmly attached at either end to the cartilages of the larynx, and are called the true vocal cords, because they function in the production of the voice.

THE TRACHEA

The trachea, or windpipe, is a fibrous and muscular tube, about four and a half inches (11.2 cm.) in length, and three-quarters of an inch (1.9 cm.) from side to side. It lies in front of the esophagus and extends from the larynx on the level of the sixth cervical vertebra, to opposite the fourth or fifth thoracic vertebra, where it divides into two tubes--the two bronchi--one for each lung.

The walls are strengthened and rendered more rigid by hoops of cartilages embedded in the fibrous tissue. These hoops are C-shaped and incomplete behind, the cartilaginous rings being completed by bands of plain muscular tissue where the trachea comes in contact with the esophagus. Like the larynx, it is lined by mucous membrane, and has a ciliated epithelium upon its inner surface. The mucous membrane, which also extends into the bronchial tubes, keeps the internal surface of the air-passages free from impurities; the sticky mucous entangles particles of dust and other matters breathed in with the air, and the incessant movements of the cilia continually sweep this dirt-laden mucous upward and outward.

NERVE SUPPLY OF THE LARYNX AND TRACHEA.--The larynx and trachea are supplied with fibers from the sympathetic and the cranial autonomic nerves. Stimulation of the sympathetic nerves causes relaxation of the muscular tissue and checks secretion. Stimulation of the cranial autonomic nerves contracts the muscular tissue and increases secretion.

THE BRONCHI

The two bronchi, into which the trachea divides, differ slightly; the right bronchus is shorter, wider, and more nearly vertical, the left bronchus is longer, narrower, and more nearly horizontal. They enter the right and left lung, respectively, and then break up into a great number of smaller branches which are called the bronchial tubes, or bronchioles. The two bronchi resemble the trachea in structure; but as the bronchial tubes divide and sub-divide their walls become thinner, the small plates of cartilage cease, the fibrous tissue disappears, the finer tubes are composed of only a thin layer of muscular and elastic tissue lined by ciliated epithelium. Each bronchiole terminates in an enlargement having more or less the shape of a funnel, and called an infundibulum. From each infundibulum there is a series of small sac-like projections known as alveoli, or air cells. The walls of the alveoli consist of a thin film of elastic tissue lined internally with a single layer of flat cells.

THE LUNGS

The lungs are cone-shaped organs which occupy the two lateral chambers of the thoracic cavity and are separated from each other by the structures contained in the MEDIASTINUM or middle space. Each lung presents an outer surface which is convex, a base which is concave to fit over the convex portion of the diaphragm, and a summit or apex which rises half an inch above the clavicle. On the inner surface is a vertical notch called the HILUM, which gives passage to the bronchi, blood-vessels, lymph-vessels, and nerves.

The right lung is the larger and heavier; it is broader than the left, owing to the inclination of the heart to the left side; it is also shorter by one inch, in consequence of the diaphragm rising higher on the right side to accommodate the liver. The right lung is divided by fissures into three lobes, upper, middle, and lower.

The left lung is smaller, narrower, and longer than the right. It is divided into two lobes, upper and lower. The front border is deeply notched to accommodate the heart.

ANATOMY OF THE LUNGS.—The lungs are hollow, rather spongy organs, and consist of the bronchial tubes and their terminal dilatations, numerous blood-vessels, lymphatics, nerves, and an abundance of fine, elastic connective tissue, binding all together. Each lobe of the lung is composed of many lobules, and into each lobule a bronchiole enters and terminates in an INFUNDIBULUM. Each infundibulum presents a series of alveoli, or air cells. In this way the amount of surface exposed to the air and covered by the capillaries is so immensely increased that it is estimated the entire inner surface of the lungs is one hundred times greater than the skin surface of the body.

BLOOD-VESSELS OF THE LUNGS.--Two sets of vessels are distributed to the lungs: (1) the branches of the pulmonary artery, which bring blood to be aerated, and (2) the branches of the bronchial arteries, which bring blood for nutritive purposes.

(1) The branches of the pulmonary artery accompany the bronchial tubes and form a plexus of capillaries around the alveoli. The walls of the alveoli consist of a single layer of flattened epithelial cells, surrounded by a fine elastic connective tissue, and are exceedingly thin and delicate. Immediately beneath the layer of flat cells, and lodged in the elastic connective tissue, is this very close plexus of capillaries; and the air reaching the alveoli by the bronchial tubes is separated from the blood in the capillaries only by the thin membranes forming their respective walls. The pulmonary veins begin at the margin of the alveoli and return the blood distributed by the pulmonary artery.

(2) The branches of the bronchial arteries supply blood to the lung substance--the bronchial tubes, coats of the blood-vessels, the lymph-nodes, and the pleura. The bronchial veins return the blood distributed by the bronchial arteries.

PLEURA.--Each lung is enclosed in a serous sac, the pleura, one layer of which is closely adherent to the walls of the chest and diaphragm (parietal); the other closely covers the lung (visceral). The two layers of the pleural sacs, moistened by serum, are normally in close contact, and the so-called pleural cavity is a potential rather than an actual cavity; they move easily upon one another, and prevent the friction that would otherwise occur between the lungs and the walls of the chest with every respiration. If the surface of the pleura becomes roughened as occurs in inflammation (pleurisy) more or less friction results and the sounds produced by this friction can be heard if the ear is applied to the chest. In health only a small amount of fluid is secreted and its absorption by the lymphatics almost keeps pace with its secretion, so that normally the amount of serum is very small. In pleurisy the amount may be considerably increased due to the extra activity of the irritated secretory cells and excessive transudation from the congested blood-vessels. The amount may be sufficient to separate the two layers of the pleura, thus changing the potential pleural cavity to an actual one. This is known as pleurisy with effusion.

MEDIASTINUM.--The mediastinum is the space left in the median portion of the thorax between the pleural sacs. It extends from the sternum to the spinal column, and contains the heart in its pericardium, the large blood-vessels connected with the heart, part of the thoracic duct, the thymus gland or vestiges of it, the trachea, esophagus, portions of the vagus and phrenic nerves.

RESPIRATION

The main purpose of respiration is to supply all the cells of the body with oxygen and rid them of the excess carbon dioxide which results from oxidation. It also helps to equalize the tem-

perature of the body and get rid of excess water. To accomplish these purposes three processes are necessary:--

(1) Breathing.--The process of breathing may be subdivided into inspiration or breathing in, and expiration or breathing out. Inspiration is a preliminary process whereby air is introduced into the lungs. Expiration is the process by which air is expelled from the lungs. This air has given up about one-fourth of its oxygen and increased the quantity of carbon dioxide one hundred times.

(2) External respiration.--This includes two processes: (a) external oxygen supply or the passage of oxygen from the alveoli of the lungs to the blood; and (b) external carbon dioxide elimination or the passage of carbon dioxide from the blood into the alveoli of the lungs.

(3) Internal respiration.--This also includes two processes: (a) oxygen supply or the passage of oxygen from the blood to the cells of the tissues; and (b) internal carbon dioxide elimination or the passage of carbon dioxide from the cells of the tissues to the blood.

It is evident that external respiration is a process that takes place in the lungs and that internal respiration is a process that takes place in all the cells that make up the tissues of the body.

MECHANISM OF INSPIRATION AND EXPIRATION.--The respiratory movements consist of an alternate outward and inward movement of the walls of the thorax, which leads first to an increase and then to a decrease in the capacity of this cavity and a corresponding change in the distention of the lungs. The first movement, inspiration, is the result of the contraction of the muscles of inspiration, the second, expiration, is mainly a passive process depending to a large extent upon the elastic recoil of the parts previously put upon the stretch. The enlargement of the thoracic cavity is accomplished in three directions: (1) dorso-ventral, (2) lateral, and (3) vertical (antero-posterior). This is brought about by the action of the intercostal and other muscles, which elevate the ribs and thereby increase the dorso-ventral and lateral diameters. The descent of the diaphragm caused by contraction of the diaphragmatic muscles increases the vertical diameter, and pushes down the neighboring abdominal viscera. The lungs are expanded exactly in proportion as the cavity in which they lie enlarges. The pressure in the alveoli is practically constant, because they communicate with the outside by means of non-collapsible tubes. The pressure in the closed thoracic cavity is variable depending on the increase and decrease in the size of the cavity.

MUSCLES OF RESPIRATION.--It is difficult to give an accurate classification of the muscles which take part in the expansion of the thorax. Usually the diaphragm and all muscles attached

to the thorax whose contraction causes an elevation of the ribs are classed as inspiratory muscles. This includes the following: (1) the levatores costarum, (2) the external intercostals, (3) the scaleni, (4) the sternocleidomastoid, (5) the pectoralis minor, and (6) the serratus posticus superior. In forced inspirations the action of these muscles is supplemented by additional muscles of the trunk, larynx, and face.

Respiratory center.—Unlike the beat of the heart the contractions of the respiratory muscles are entirely dependent on the nervous system, especially that part known as the respiratory center, which is located in the medulla oblongata, or hind brain. Some authorities call attention to the fact that normal respiration consists of an active inspiration and a passive expiration. Because the stimulation from the respiratory center produces the coordinated activity of the inspiratory muscles, it is suggested that this center might be designated the inspiratory center.

The respiratory center shows a specific irritability for carbon dioxide, and an increased amount of carbon dioxide in the blood acts as a stimulus, increasing the rate and depth of the respirations, so that the lungs are more thoroughly ventilated. An increased amount of carbon dioxide is usually associated with a lack of sufficient oxygen, and for many years there was much difference of opinion as to which of these two conditions was the more effective stimulant of the respiratory center.

Oxygen, nitrogen and carbon dioxide.—A small portion of oxygen is held in solution, but by far the greater portion is held in chemical combination with the hemoglobin of the red cells. The amount of oxygen so held depends upon the quantity of hemoglobin in the blood, and the pressure of oxygen in the alveoli. It is thought that nitrogen in the blood is held in physical solution. The condition in which carbon dioxide is held in the blood is not well understood, but it is thought that a small percentage is held in solution, a larger amount in the form of sodium bicarbonate ($HNaCO_3$), and a still larger amount in the form of organic compounds.

	Oxygen	Carbon dioxide	Nitrogen
Venous blood contains..........	8-12%	45-50%	1.7%
Arterial blood contains........	20%	38%	1.7%

Capacity of the lungs.—It has been stated that after the lungs are once filled with air they are never completely emptied again until after death. In other words, no expiration ever completely empties the alveoli, neither are they completely filled.

The quantity of air which a person can expel by a forcible expiration, after the deepest inspiration possible, is called the vital capacity, and averages about 3500 to 4000 cc. It is the sum of tidal, complemental and supplemental air.

Tidal air designates the amount of air that flows in and out of the lungs with each quiet respiratory movement. The average figure for the adult is 500 cc.

Complemental air designates the amount of air that can be breathed in over and above the tidal air by the deepest possible inspiration. It is estimated at 1600 cc. (3 pts.).

Supplemental air is the amount of air that can be breathed out after a quiet expiration by the most forcible expiration. It is equal to 1600 cc.

Residual air is the amount of air remaining in the lungs after the most powerful expiration. This has been estimated on the cadaver and is about 1000 cc. (2 pts.).

Reserve air equals the residual air plus the supplemental air in the lungs under conditions of normal breathing, that is, about 2600 cc. (5 pts.).

	Oxygen	Carbon Dioxide	Nitrogen
Inspired air............	20.96%	0.04%	79%
Expired air.............	16.02%	4.38%	79%
	4.94 loss	4.34 gain	0

RESPIRATORY PHENOMENA

Each intake of air is accompanied by a fine rustling sound which can be heard if the ear is applied to the chest wall. It is thought that the dilatation of the alveoli produces this sound, and absence of it indicates that the air is not entering the alveoli over which no sound is heard, or that the lung is separated from the chest wall by effused fluid. The air passing in and out of the larynx, trachea and bronchial tubes produces a louder sound which is called a bronchial murmur. Normally this murmur is heard directly above or behind the tubes, but when the lung is consolidated as in pneumonia, it conducts sound more readily than usual and the murmur is heard in other parts of the chest. In diseased conditions the normal sounds are modified in various ways, and are then spoken of under the name of rales.

Eupnea.—This term is applied to ordinary quiet respiration made without obvious effort.

Dyspnea.--The word dyspnea is applied to difficult or labored breathing. It is caused by (1) an increase in the percentage of carbon dioxide in the blood, (2) a decrease of oxygen, (3) any condition that stimulates the sensory nerves and causes pain in the lungs, and (4) any condition that interferes with the normal rate of the respirations or of the heart action, or prevents the passage of air in and out of the lungs.

Hyperpnea.--The word hyperpnea is applied to the initial stages of dyspnea, when the respirations are simply increased.

Apnea.--The word apnea means a lack of breathing.

Cheyne-Stokes respiration.--This is a type of respiration which was first described by the two physicians whose names it bears. Its actual cause is not understood, but it is associated with conditions that depress the respiratory center, especially in brain, heart and kidney diseases. It appears in two forms: (1) the respirations increase in force and frequency up to a certain point, and then gradually decrease until they cease altogether, and there is a short period of apnea, then the respirations recommence and the cycle is repeated. (2) The respirations increase in force and frequency up to a certain point, then cease, and the period of apnea intervenes, without the gradual cessation of the respirations.

Asphyxia.--Asphyxia is produced by any condition that causes prolonged interference with the aeration of the blood, viz., obstruction to the entrances of air to the lungs, depression of the respiratory center, an insufficient supply of oxygen, or a lack of hemoglobin in the blood. The first stages are associated with dyspnea and convulsive movements, then the respirations become slow and shallow and are finally reduced to more twitches. The skin is cyanosed, the pupils of the eyes dilate, the reflexes are abolished and respirations cease. If the heart continues to beat, resuscitation is often accomplished by artificial respiration even after breathing has ceased.

CHAPTER V

THE CIRCULATORY SYSTEM

THE BLOOD

It is helpful to recall that the body consists of an enormous number of individual cells, and that each cell must be supplied with materials to enable it to carry on its activities, and at the same time it must have the waste materials that are the result of its activities removed. Many cells are far from the source of supplies and the organs of elimination; hence the need of a medium to distribute supplies and collect waste, and the need of a system so that the distribution will be orderly and systematic. These two needs are met by the vascular system, the divisions of which may be outlined as follows:

VASCULAR SYSTEM	Circulating fluids---	Blood. Lymph.
	Systems--------------	Blood vascular. Lymph vascular.

Some histologists classify blood and lymph as varieties of connective tissue known as liquid tissues because they consist of cells and intercellular substance, though with this difference: the intercellular substance is liquid and is not wholly derived from the cells but procured from several other sources.

CHARACTERISTICS.--The most striking external feature of the blood is its well-known color, which is blood red, approaching to scarlet in the arteries, but of a dark red or crimson tint in the veins.

It is a somewhat sticky liquid, a little heavier than water; its specific gravity averages about 1.055. It has a peculiar odor, a saltish taste, a slightly alkaline reaction when tested with litmus, and a temperature of about 100° F. (37.8° C.).

QUANTITY OF BLOOD.--The quantity of blood contained in the body of an adult is estimated to be about 1/20 of the body weight. This, in an individual weighing 160 pounds (80 kilos), would weigh about 8 pounds (4 kilos), or measure 4 quarts (4 liters).

FUNCTIONS OF THE BLOOD.---Blood is commonly spoken of as the nutritive fluid of the body. This is correct, but it is more than a nutritive fluid, as will be seen from the following list of its functions:--

(1) It serves as a medium for the interchange of gases, e.g., carries oxygen to the cells and carbon dioxide from the cells.

(2) It serves as a medium for the interchange of nutritive and waste materials. It carries food to the cells and waste ma-

CIRCULATORY SYSTEM
(Schematic)

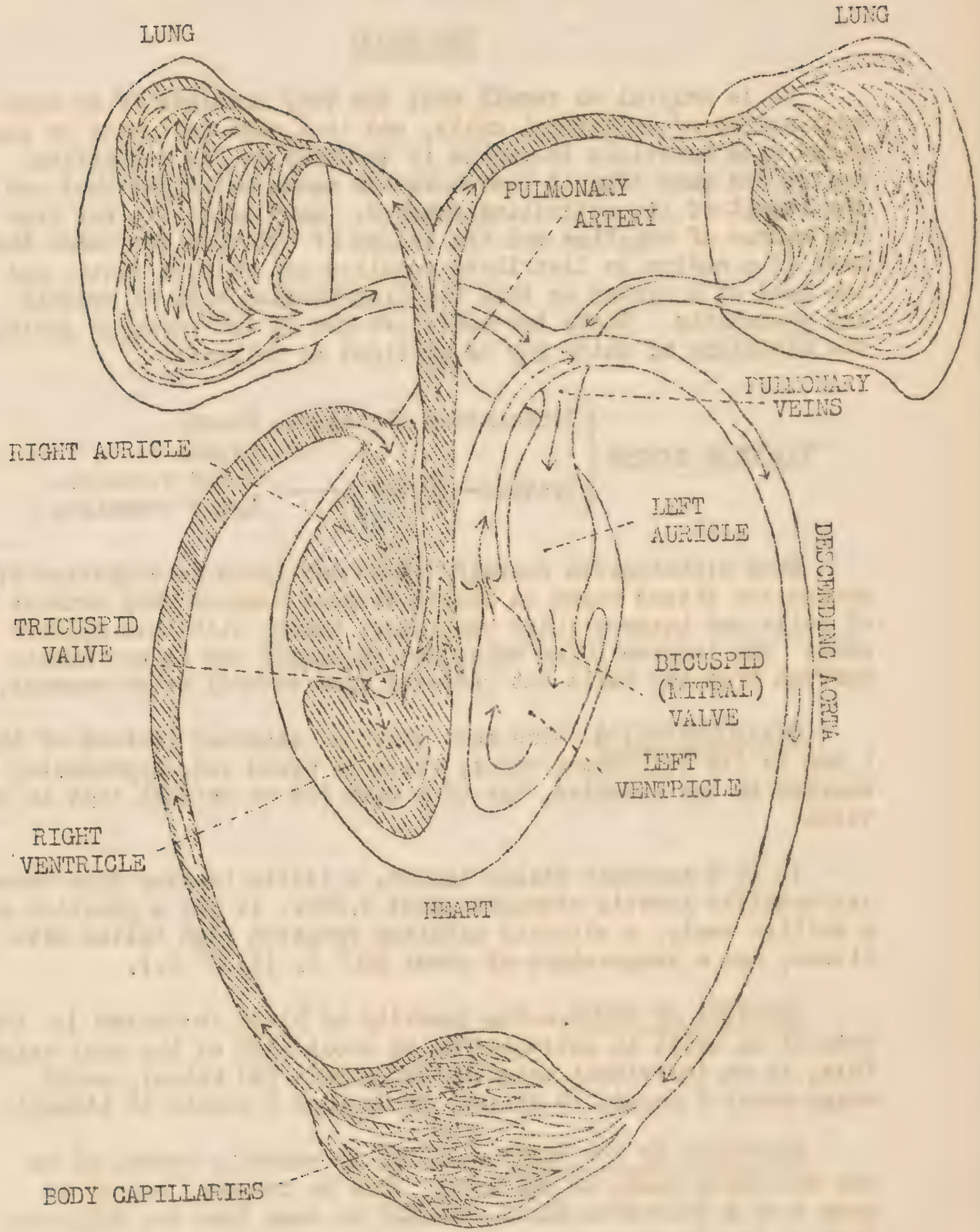


Fig. 6

terials from the cells.

(3) It serves as a medium for the transmission of internal secretions. The presence of these secretions controls the chemical activities of cells.

(4) It aids in equalizing the temperature of the body. Blood passing through a tissue which is undergoing lively metabolism will have a higher temperature when it leaves than it had when entered. This extra temperature will be lost in passing through a tissue that is not so active. In this way an average temperature is maintained.

(5) It aids in protecting the body from toxic substances.

COMPOSITION OF THE BLOOD.--Seen with the naked eye, the blood appears opaque and homogeneous; but when examined with a microscope it is seen to consist of minute, solid particles called cells or corpuscles floating in a transparent, slightly yellowish fluid called plasma.

$$\text{BLOOD} \begin{cases} \text{Cells or Corpuscles} \rightarrow \begin{cases} \text{Red, or erythrocytes,} \\ \text{White, or leucocytes.} \\ \text{Blood-platelets, or thrombocytes.} \end{cases} \\ \text{Plasma} \end{cases}$$

RED CELLS.--The red cells are usually described as being circular bi-concave discs, with rounded edges. The average size is about 1/3200 of an inch (0.008 mm.) in diameter. Because of their extremely small size, the red cells do not appear red when viewed singly with a microscope, but merely of a yellowish red tinge, or yellowish green in venous blood. It is only when great numbers of them are gathered together that a distinctly red color is produced.

HEMOGLOBIN.--Hemoglobin is a substance which is formed of hematin, an iron salt, and a protein named globin. In the presence of oxygen it has the power to combine with it to form an unstable compound called oxyhemoglobin, and in an environment where oxygen is scarce, it gives up this oxygen, and is then known as reduced hemoglobin. Every 100 grams of blood contains about 14 grams of hemoglobin in men, and a little less in women.

FUNCTION OF THE RED CELLS.--The red cells, or erythrocytes, by virtue of the hemoglobin which they contain, are emphatically oxygen carriers. Exposed to the air in the lungs the hemoglobin becomes fully charged with detachable oxygen and is known as oxyhemoglobin. The red cells carry this oxyhemoglobin to the tissues, where it gives up the loosely engaged oxygen. It is then known as reduced hemoglobin and is ready to be carried to the lungs for a fresh supply. The color of the blood is dependent upon the combination of the hemoglobin with oxygen;

when the hemoglobin has its full complement of oxygen, the blood has a bright red hue; when the amount is decreased, it changes to a dark crimson hue. The scarlet blood is usually found in the arteries, and is called arterial; the dark crimson in the veins, and is called venous blood.

Number of Red Cells.--The average number of red cells in a cubic millimeter of healthy blood is given as 5,000,000 for men and 4,500,000 for women. The number varies with altitude; temperature; the constitution, nutrition, and manner of life; with age, being greatest in the fetus and new-born child; with the time of day, showing a diminution after meals; in the female menstruation is accompanied by an increase and pregnancy by a decrease.

Anemia.--This term is applied to conditions associated with a deficiency of red cells, or a deficiency of hemoglobin in the cells. A deficiency of red cells results from: (1) hemorrhage, (2) hemolysis, (3) inability to produce new red cells due to lack of nutritious food, diseases of the bone-marrow, and various infections. If the number of cells is normal it is reckoned as 100 percent and if the hemoglobin is reduced to 70 percent this gives us 70/100 or 7/10 and shows that the cells contain 7/10 of their normal amount of hemoglobin.

Life Cycle of the Red Cells.--The red cells, like all the cells of the body, have a definite term of existence. Under normal conditions of health the red marrow is the only location in which red cells are formed after birth. Conditions caused by a decrease in the number of red cells normally act as a stimulus for their formation and hasten their passage into the blood-stream. Following hemorrhage or any condition which causes a marked diminution in the number of red cells, nucleated cells will pass into the blood stream, and the yellow marrow, liver, and spleen may again function as locations for the formation of erythrocytes. Erythrocytes have no nuclei, hence they are not living cells and are (1) incapable of independent motion, (2) repairing their own waste, or (3) reproducing themselves. They move along passively in the blood-stream and gradually undergo disintegration. Their final destruction takes place chiefly in the liver, and to a lesser extent in the spleen. The hematin set free from the destroyed cells is changed to bile-pigment. Some of the iron liberated is excreted but most of it is retained and utilized for the formation of fresh hemoglobin, needed by the new cells being formed in the bone-marrow.

WHITE CELLS.--The white cells appear as small globules of protoplasm containing a nucleus, sometimes two or three nuclei. They are variable in size, some are much larger and some are much smaller than the red cells. They are grayish (not white) in color, and not surrounded by a clearly recognizable membrane.

Number of White Cells.--The number of white cells in a cubic millimeter of healthy blood is from 6000 to 10,000, a proportion of about one white to 700 red. A marked increase in number is designated as leucocytosis, a marked decrease as leucopenia.

Varieties of White Cells.--The white cells may be arranged in groups, according to the shape and size of their cell bodies and nuclei, or according to the way in which they behave toward anilin dyes. They are usually divided into two principal groups and these again into several others, as follows:

1. LYMPHOCYTES
   - (a) Small type.
   - (b) Large type.
2. LEUCOCYTES
   - (a) Transitional type or mononuclear.
   - (b) Polymorphonuclear
     - Neutrophils.
     - Eosinophils.
   - (c) Basophil.

FUNCTIONS OF THE WHITE CELLS.--The most important functions are: (a) they help to protect the body from bacteria; (b) they help to disintegrate tissue cells that have been destroyed and carry away the products of this disintegration; (c) they absorb the digested fat from the intestines and carry it into the lymphatics, whence it reaches the blood; (d) it is thought they aid in the absorption of proteins and help to maintain the protein content of the blood; (e) they contain a substance which when liberated plays an important part in the clotting of the blood.

Inflammation.--When any of the tissues become inflamed either as the result of injury or infection, the first effect is irritation, followed by an increased supply of blood to the part. If the irritation continues or is severe, the flow of blood begins to slacken, and a condition of stasis or engorgement results. The leucocytes become particularly active and migrate into the infected tissues in large numbers. Some of the blood-plasma exudes, and a small number of red cells are forced through the capillary walls. This general condition is described as inflammation, and the symptoms are (1) pain, (2) heat, (3) redness, (4) swelling and loss of function. Under these conditions a death struggle between the leucocytes and bacteria takes place. If the leucocytes are victorious, they not only kill the bacteria but remove every vestige of the struggle, and find their way back to the blood. This process of recovery is described as resolution, and is dependent upon the individual's resistance, i.e., the rapid formation of phagocytes and opsonins.

If the bacteria are victorious, large numbers of phagocytes and tissue cells will be destroyed and suppuration, i.e., the formation of pus ensues. Pus consists of dead and living

bacteria, phagocytes, disintegrated tissue cells, and material that has exuded from the blood-vessels.

BLOOD-PLATELETS OR THROMBOCYTES.--They are disc-shaped bodies, which vary in size but are always smaller than the red cells. Their origin and fate are still open questions.

Function.--The function of blood-platelets is to provide substances that help in the clotting of blood. When exposed to air and rough surfaces, (conditions accompanying a wound and hemorrhage) large numbers of blood-platelets are disintegrated and set free a substance known as thrombokinase. They also help to furnish the blood with prothrombin. Both of these substances are essential to clotting.

PLASMA.--The plasma of the blood is a complex fluid of a clear amber color containing a great variety of substances as might be inferred from its double relation to the cells, having service as a source of nutrition and as a means of removing the waste products that result from their functional activity. More than nine-tenths of the plasma is water. This proportion is kept fairly constant by kidney activity coupled with rapid exchanges of fluid which take place between the blood, the lymph and the tissues.

SALTS.--The salts found in the blood are derived from the food and from the chemical reactions going on in the body. The most abundant is sodium chloride.

GASES.--Oxygen, nitrogen, and carbon dioxide gas are found in the blood. Carbonic acid (H_2CO_3) is continually entering the blood from the tissues, but the blood contains certain buffer substances, i.e., sodium bicarbonate, sodium phosphate, and proteins which enter into loose combination with the carbon dioxide so that there is only about 5 percent present in simple solution.

INTERNAL SECRETIONS.--The blood serves as a medium to carry internal secretions.

ENZYMES.--The blood serves as a medium to carry enzymes.

SPECIAL SUBSTANCES.--Antithrombin and prothrombin are considered in connection with the clotting of blood.

ANTIBODIES.--Under this heading are classed certain substances which help to produce immunity, i.e., protection against diseases caused by micro-organisms. Certain substances on entering the body stimulate the production of other substances to act against them. The stimulating substance (often bacteria) is called an antigen, and the substance that acts against it is an antibody. Most of the antibodies are more or less specific, i.e., they only act against the antigens that stimulate their production. Antitoxins are substan-

ces formed by the cells of the body to couteract the effects of the toxins by micro-organisms.

Thrombus and Embolus.--A clot which forms inside a blood-vessel is called a thrombus. A thrombus may be broken up and disappear, but the danger is that it may be carried to some point in an important vessel where it acts as a wedge, blocks circulation, and may cause instant death. A thrombus that becomes dislodged from its place of formation is called an embolus.

THE CIRCULATORY SYSTEM

The blood is contained in branched tubes named blood-vessels. It is driven along these tubes by the action of the heart, which is a hollow muscular organ placed in the center of the vascular system. One set of vessels--the arteries--conducts the blood out from the heart and distributes it to the different parts of the body, while other vessels--the veins--bring it back to the heart again. The blood from the arteries gets into the veins by passing through a network of fine tubes which connect the two, and which are named, on account of their small size, the capillary (hair-like) vessels.

BLOOD VASCULAR SYSTEM	Heart. Arteries--small arteries are named arterioles. Capillaries. Veins--small veins are named venules.

HEART

The heart is a hollow, muscular organ, situated in the thorax between the lungs, and above the central depression of the diaphragm. It is about the size of the closed fist, shaped like a blunt cone, and so suspended by the great vessels that the broader end or base is directed upward, backward, and to the right. As placed in the body, it has a very oblique position, and the right side is almost in front of the left. The impulse of the heart against the chest wall is felt in the space between the fifth and sixth ribs, a little below the left nipple, and about 8 cm. (3 in.) to the left, of the median line.

MYOCARDIUM.--The main substance of the heart is composed of muscular tissue and is called myocardium.

PERICARDIUM.--The heart is covered by a membranous sac called the pericardium (around the heart). It consists of two parts: (1) an external fibrous portion, and (2) an internal serous portion.

THE CAVITIES OF THE HEART.--The heart is divided from the base to the apex, by a fixed partition, into a right and left half, frequently called right and left heart. The two sides of the heart have no communication with each other after birth. The right side always contains venous, and the left side arterial, blood. Each half is subdivided into two cavities, the upper, called auricle (atrium); the lower, ventricle (ventriculum). If we examine these cavities, we notice that the muscular walls of the auricles are much thinner than those of the ventricles, and the wall of the left ventricle is thicker than that of the right (the proportion being 3 to 1). This difference in bulk is to be accounted for, as we shall see later on, by the greater amount of work the ventricles, as compared with the auricles, have to do. These cavities

communicate with one another by means of constricted openings, the auriculoventricular orifices, which are strengthened by fibrous rings and protected by valves.

BLOOD SUPPLY OF THE HEART.--Just after the aorta leaves the left ventricle it gives off two small branches, called the right and left coronary arteries. They encircle the heart like a crown, hence their name. They supply the substance of the heart with blood, as the blood contained within the cavities of the heart only nourishes the endocardium. The blood from the coronary arteries is returned by a coronary vein to the right auricle.

NERVE SUPPLY OF THE HEART.--The heart is supplied (1) by the vagi nerves from the central nervous system and (2) by nerves from the autonomic system. Stimulation of the vagi fibers slows the action of the heart. They are therefore known as cardiac inhibitors. Stimulation of the autonomic nerves increases the force of the heart beat, therefore they are known as cardiac accelerators.

ARTERIES

The arteries are tubes that carry blood from the heart and break up into capillaries. They are composed of three coats:--

1. An inner endothelial lining which is continuous with the endothelium lining the heart. It furnishes a smooth, slippery surface over which the blood can flow without friction.

2. A middle coat of fibrous elastic tissue with muscles interlaced and circularly disposed around the vessel. By virtue of the structure of the middle coat, the arteries are both extensile and elastic.

> If we tie a piece of a large artery at one end and inject fluid into the other end, the artery swells out to a very great extent, but will return at once to its former size when the fluid is let out.

3. An outer, dense fibrous coat with fibers arranged longitudinally. The strength of an artery depends largely upon the outer fibrous coat; it is far less easily cut or torn than the other coats, and serves to resist undue expansion of the vessel.

The arteries do not collapse when empty, and when an artery is severed the orifice remains open. The muscular coat, however, contracts somewhat in the neighborhood of the opening, and the elastic fibers cause the artery to retract a little within its sheath, so as to diminish its caliber and permit a blood-clot to plug the orifice. This property of the severed artery is an important factor in the arrest of hemorrhage.

SIZE OF THE ARTERIES.--The largest arteries in the body, the aorta and pulmonary artery, measure about one inch (2.8 cm.) in diameter, at their connection with the heart. These arteries give off branches, which divide and subdivide into smaller branches. A branch of an artery is always less than the trunk from which it springs, hence the arteries grow smaller as they subdivide, and gradually lose their characteristic structure. The smallest arteries are called arterioles, and at their distal ends, where only the internal coat remains, the capillaries begin.

CAPILLARIES

The capillaries are exceedingly minute vessels which average about 1/2000 of an inch (.0125 mm.) in diameter. They connect the arterioles (smallest arteries) with the venules (smallest veins), thus receiving the blood from the arterioles and carrying it to the venules.

STRUCTURE.--The walls of the capillaries are formed entirely of one layer of simple endothelium composed of flattened cells joined edge to edge by cement substance, and continuous with the layer which lines the arteries and veins.

DISTRIBUTION.--The capillaries communicate freely with one another and form interlacing networks of variable form and size in the different tissues. All the tissues, with the exception of the cartilages, hair, nails, cuticle, and cornea of the eye, are traversed by these networks of capillary vessels. Their diameter is so small that the blood cells must pass through them in single file and very frequently the cell is larger than the caliber of the vessel, and has to be squeezed to enable it to pass through.

VEINS

The veins are tubes that carry blood to the heart, and are made by the gathering together of the capillaries. They have three coats and on the whole resemble the arteries in structure. They differ from them in having: (1) much thinner walls; (2) they contain less elastic tissue, more white fibrous tissue, and because of this are not so elastic or contractile as the arteries; (3) many of the veins are provided with valves.

VALVES.--The valves are semilunar folds of the internal coat of the veins; and usually consist of two flaps, rarely one or three.

The convex border is attached to the side of the vein, and the free edge points toward the heart. Their function is to prevent regurgitation and keep the blood flowing in the right direction, i.e., toward the heart.

If for any reason the blood on its onward course toward the heart is driven backward, the refluent blood, getting between the wall of the vein and the flaps of the valve, will press them inward until their edges meet in the middle of the channel and close it.

The valves are most numerous in the veins where regurgitation is most likely to occur, i.e., the veins of the extremities. For the same reason a greater number are found in the lower than in the upper limbs. They are absent in many of the small veins, in the large veins of the trunk, and in veins not subjected to muscular pressure. The veins, like the arteries, are supplied with both blood-vessels and nerves; the supply, however, is far less abundant.

PHYSIOLOGY OF THE CIRCULATORY SYSTEM

(SUMMARIZED)

The main portion of the heart is composed of muscular tissue called the myocardium. Some of the muscles of the heart run transversely, others longitudinally, others obliquely, while those in the apex make a spiral turn or twist. This intricate arrangement makes it possible for an even and complete closing of the heart cavities during contraction. The heart is divided vertically into two halves which do not have any opening between so that we really have two hearts, a right and left. Each side of the heart is made up of two cavities, an auricle and a ventricle, the auricles being smaller, thinner walled, and situated above the ventricles. The right side of the heart is called the venous side, as it receives into its auricle the impure blood collected by the veins. The venous blood enters the right auricle, from there it passes through the tricuspid valve into the right ventricle. The blood is then forced through the pulmonary valve into the pulmonary artery passing through the lungs where it is purified. The blood is then picked up from the lungs by the pulmonary veins and passes into the left auricle. From the left auricle it passes through the mitral valve into the left ventricle and from there is expelled through the aortic valve into the aorta. The heart is nourished by blood supplied it through the right and left coronary arteries and its nerve supply is from the pneumogastric nerve and the sympathetic nervous system. The central nervous system can control and regulate the rhythmical, automatic contractions of the heart which are continuous during life but it has nothing to do with the cause of these contractions, whose origin is not definitely known. The heart action consists of wave-like contractions, beginning in the auricles and passing to the ventricles, followed by dilatations. These contractions and dilatations are alternate and continuous and occur normally at the rate of about 72 per minute, although this rate varies according to age, sex, exercise, temperature, and in some pathological conditions. Contractions or systole is a period of work. Dilatations, or "diastole", is a period of rest or relaxation. The system of arteries and arterioles may be compared to a tree with a trunk, giving off main branches which divide and subdivide again and again until they are but minute twigs. The arteries are constantly carrying a pulsating stream of blood which leaves the arterial tree at the finest subdivision and passes into the network of capillaries. In many locations, arteries that arise from different sources join together to form a union called anastomosis. The capillaries have very thin walls and form a dense network throughout the body, and it is through these networks that the blood comes in contact with the tissues of the body in order to give up food and oxygen and take away the various waste products. The veins

begin as small branches called venules which unite to form larger vessels. Veins differ from arteries in that they have a larger capacity, thinner walls, and contain valves which act in assisting in the support of the column of blood. This is necessary because most of the cardiac impulse is lost during the course of blood through the capillaries.

BLOOD-PRESSURE.--Blood pressure is the force of the blood exerted against the walls of the vessels in which it is contained. Although the term includes the pressure in the arteries, veins, and capillaries, the usual application of the term is to arterial pressure alone. The highest pressure is known as the "systolic" blood pressure. Under normal conditions in the young adult this pressure is equivalent to about 120 millimeters of mercury. A certain amount of blood pressure is maintained in the arteries during the period of cardiac relaxation. This is caused by the elasticity and tonicity of the arteries and by the peripheral resistance. This pressure is known as the "diastolic" blood pressure and in normal young adults it is equivalent to about 70 to 90 millimeters of mercury.

THE LYMPH SYSTEM

The blood does not come into immediate contact with the cells, but is separated from them by the walls of the capillaries. This necessitates a medium of exchange between the blood and the cells. Lymph serves this purpose.

SOURCES OF LYMPH.—By the action of physical and chemical processes, the details of which are not entirely understood, the plasma of the blood makes its way through the thin walls of the capillaries into such spaces as exist between the cells forming the tissues. Some physiologists claim that the combined action of the physical processes of filtration, diffusion and osmosis, is sufficient to account for the formation of lymph. Others claim that in addition it is necessary to assume an active secretory process on the part of the endothelial cells composing the capillary walls. This plasma plus the leucocytes that have left the vessels by migration make up the lymph.

It has been suggested that the term lymph be applied to the fluid contained in the lymphatic channels only, while that part of it found in the tissue-spaces, bathing the individual cells, be designated tissue-fluid. The reason given for this distinction is that the lymph in the lymph-vessels differs in composition from the fluid found in the tissues. On the other hand, it is argued that lymph originates in all parts of the body, and all types of lymphatic fluids contribute to its formation. Consequently it seems desirable to class as lymph the fluids found in the lymph-vessels; in the tissues; in the different serous-spaces of the body, i.e., the pericardial, pleural and peritoneal cavities; and in the spaces of the cerebrum, spinal cord, eyes, ears and joints. In addition the lymph that fills the lacteals of the intestinal villi is milky in appearance due to the absorption of fat, and is called chyle.

LYMPH.—The composition of lymph is similar to that of the plasma from which it is derived, but since the capillary wall serves as a filter, the plasma can only pass through in a much diluted form. It is a colorless or yellowish fluid possessing an alkaline reaction, a salty taste, and a faint odor.

When examined under the microscope, it is seen to consist of a clear liquid with cells floating in it. Its resemblance to the blood-plasma is indicated in the following table:

BLOOD	LYMPH
Specific gravity about 1.055.	Specific gravity varies between 1.015 and 1.023.
Contains red cells.	May contain red cells.
Contains white cells.	Contains white cells.
Contains blood-platelets.	Does not contain blood-platelets.
A high content of proteins.	A low content of proteins.
A low content of waste products.	A higher content of waste products.
Normally--clots quickly and firmly.	Clots slowly and does not form a firm clot.

FUNCTIONS OF THE LYMPH.--The lymph bathes all portions of the body not reached by the blood. It delivers to the cells the material each cell needs to maintain its functional activity, which products may be simple waste, or matters capable of being made use of by some other tissues. There is thus a continual interchange going on between the blood and the lymph. This interchange is effected by means of osmosis and dialysis.

The chyle, or lymph of digestion, absorbs nutrient materials (mostly fat) from the intestines and pours this food into the blood current, to be distributed to all parts of the body.

LYMPH VASCULAR SYSTEM

As the process of lymph formation is continual, it follows that edema would result from the accumulation of lymph if some system of drainage were not provided to return the lymph to the blood. This drainage system is called the lymph vascular system, or the Lymphatic system.

Lacteals.--The lymphatics that have their origin in the villi of the small intestine are called lacteals. During the period of intestinal digestion they are filled with chyle, which has a white aspect, due to fat absorbed from the food, and suspended in it like oil in milk. After fasting, the lacteals contain lymph which differs very little from the lymph found in the ordinary lymphatics.

FUNCTION OF THE LYMPHATICS.--The function of the lymphatics is to carry from the tissues to the veins all the materials which the tissues do not need. Functionally they may be considered between the capillaries and the veins, as they gather up the lymph which exudes through the thin capillary walls, and return it to the innominate veins. Here it becomes mixed with the blood, enters the superior vena cava, and then the right auricle of the heart. The function of the lacteals is to help in the absorption of digested food, especially fats.

LYMPH-NODES.--The lymph-nodes are numerous round or ovoid bodies placed in the course of the lymphatics. They vary in size from a pinhead to an almond. A lymph-node is covered by a thin capsule consisting of fibrous and in some cases muscular tissue.

Location of Nodes.--There is a superficial and a deep set of nodes, just as there is a superficial and a deep set of lymphatics and veins. Occasionally a node exists alone, but they are usually in groups or in chains at the sides of the great blood-vessels. They are found in great numbers in the neck, thorax, axilla, groin, mesentery, and alongside of the aorta, inferior vena cava, and the iliac vessels. A few are found in the popliteal space and in the arm as far as the elbow, but none farther down the leg or forearm. They are usually named from the position in which they are found in the body; viz, cervical in the neck, thoracic in the thorax, axillary in the axilla, inguinal in the groin, mesenteric in the mesentery.

FUNCTIONS OF THE LYMPH-NODES.--The lymph-nodes serve two important purposes:

(1) Multiplication of lymphocytes.--In its passage through the node the lymph takes up fresh lymphocytes, which are continually multiplying by cell division in the substance of the node, which is considered the birthplace of these cells.

(2) As filters for the lymph.--In this way they act as safety-valves and serve to retard the spread of infection through the body. If any portion of the body is infected, the bacteria may be carried by the lymphatics to their special nodes. There its course is stopped. Foreign substances such as bacteria are caught in the sieve-like network of lymphoid tissue and the lymphocytes together with the phagocytes contained in the lymph try to destroy them. Unless the infection is very severe, the chances are against the bacteria on account of the large number of white cells present in the nodes. If the bacteria win out, the infected material is discharged into the lymph and ultimately into the blood, unless the lymph traverses other nodes where the white cells are more successful.

THE DIGESTIVE SYSTEM

In complex multicellular bodies, the cells where food is needed are so far removed from the points of entrance of food material, that it is necessary that these foods should be changed physically and chemically into such standard substances as can diffuse into the blood system and be carried by the blood to all the cells of the body and diffuse into them. Chemical and physical changes necessary to reduce our varied foods to such standard substances as the tissues can use are effected in certain organs that are grouped together and called the digestive system.

The digestive system consists of the alimentary canal and the accessory organs: (1) the salivary glands, (2) the tongue, (3) the teeth, (4) the pancreas, and (5) liver.

ALIMENTARY CANAL

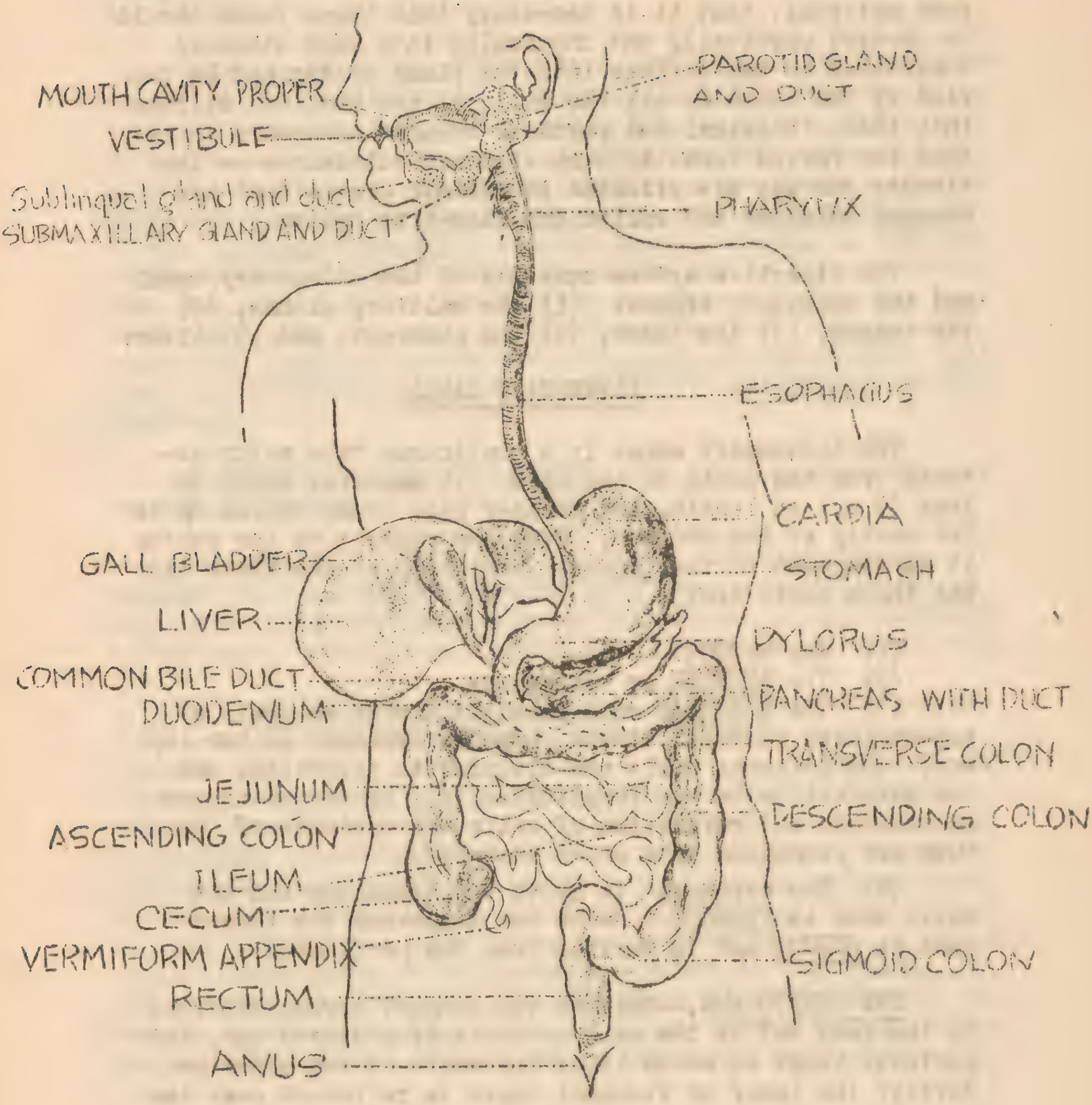
The alimentary canal is a continuous tube which extends from the mouth to the anus. It measures about 30 feet (9 m.) in length, the greater part being coiled up in the cavity of the abdomen. From the pharynx to the rectum it is composed of four coats. Beginning at the inner lining these coats are:

(1) The MUCOUS
(2) The AREOLAR or sub-mucous.
(3) The MUSCULAR coat consists almost entirely of non-striated muscular tissue, usually arranged in two layers. The internal cells are circular in direction, and the external cells run longitudinally. By the alternate contraction and relaxation of cells the contents of the tube are propelled from above downward.

(4) The esophagus is above the diaphragm and the outer coat is FIBROUS. Below the diaphragm the fourth coat is SEROUS and is derived from the peritoneum.

THE PERITONEUM.--This is the largest serous membrane in the body and in the male consists of a closed sac, the parietal layer of which lines the walls of the abdominal cavity; the inner or visceral layer is reflected over the abdominal organs, and the upper surface of some of the pelvic organs. The arrangement of the peritoneum is very complex, for several elongated sacs and double folds extend from it, to pass in between and either wholly or partially surround the viscera, of the abdomen and pelvis. One important fold is the omentum, which hangs like a curtain in front of the stomach and the intestines; another is the mesentery, which is a continuation of the serous coat and attaches the small and much of the large intestine to the spine.

When the abdominal cavity is opened, the intestines lie within the cavity like a loose coil of rope (in appearance); if,



THE DIGESTIVE SYSTEM

FIG. 7

however, an attempt is made to lift a coil from its place a clear, glistening sheet of tissue is found attached to it. This is the mesentery. The posterior portion is gathered into folds which are attached to the spine along a short line of insertion which results in a structure that has the appearance of a ruffle or flounce.

FUNCTIONS OF THE PERITONEUM.—Like all serous membranes the peritoneum serves to prevent friction between contiguous organs by secreting serum which acts as a lubricant. To a limited extent it serves to hold the abdominal and pelvic organs in position, also unites and separates these organs. In addition to these functions, the omentum usually contains fat, and serves to keep the organs it covers warm.

DIVISIONS OF THE ALIMENTARY CANAL.—For convenience of description, the alimentary canal may be divided into:

Mouth, containing tonsils, tongue, salivary glands, and teeth.
Pharynx.
Esophagus.
Stomach.

Small or thin intestine	Duodenum. Jejunum. Ileum.	
Large or thick intestine	Cecum. Colon. Rectum.	Ascending. Transverse. Descending.

THE ESOPHAGUS OR GULLET

The esophagus is a comparatively straight tube, about nine inches (22 cm.) long, which commences at the lower end of the pharynx, behind the trachea. It descends in front of the spine, passes through the diaphragm, and terminates in the upper or cardiac end of the stomach.

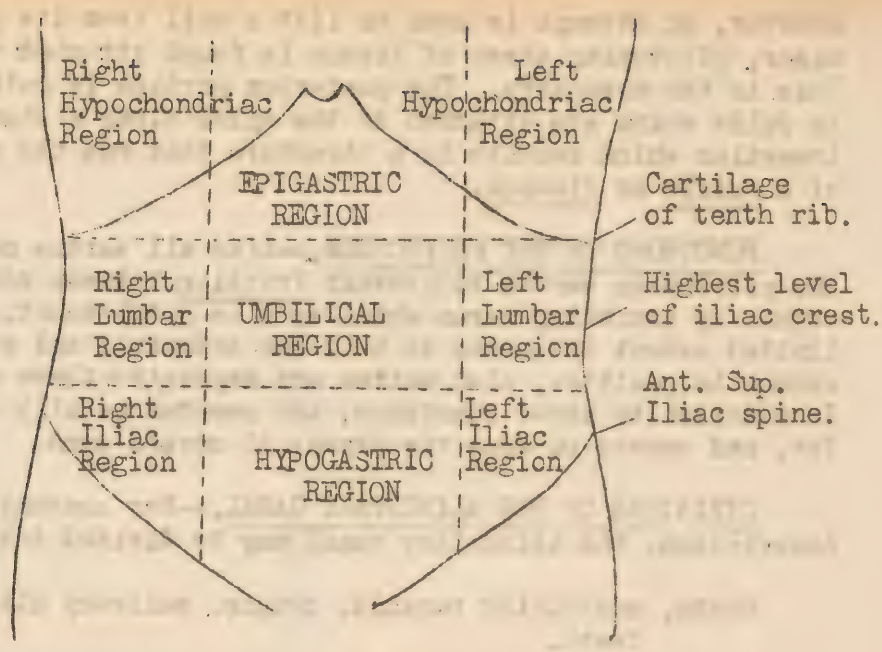


Fig. 8.

STRUCTURE.—The walls of the esophagus are composed of four coats: (1) an external or fibrous, (2) a muscular, (3) an areolar, and (4) an internal or mucous coat. The muscular coat is arranged in an external longitudinal and an internal circular layer. Contraction of the outer layer produces dilatation of the tube; contraction of the inner, constriction. Consequently this arrangement is of importance in the movements which carry the food from the pharynx to the stomach. These movements are called peristaltic, and consist of contractions of the longitudinal layer, followed by contractions of the circular layer. The areolar coat serves to connect the muscular and mucous coats. The mucous membrane is disposed in longitudinal folds which disappear upon distention of the tube, caused by the passage of food. It is studded with minute papillae and small glands which secrete mucus to lubricate the canal.

FUNCTION.—The esophagus serves (1) to connect the pharynx with the stomach, and (2) to receive the food from the pharynx and by a series of peristaltic contractions pass it on to the stomach.

REGIONS OF THE ABDOMEN.—That portion of the alimentary canal which is below the thorax is contained in the abdomen. For convenience of description, the abdomen may be artificially divided into nine regions, as illustrated in Figure 8.

THE STOMACH

After the esophagus perforates the diaphragm it ends in the stomach (gaster), which is a collapsible sac-like dilatation of the alimentary canal and serves as a temporary recep-

tacle for food. It lies obliquely or horizontally in the epigastric and left hypochondriac regions of the abdomen, directly under the diaphragm. The shape and position of the stomach are modified by changes within itself, and in the surrounding organs. These modifications are determined by (1) the amount of the stomach contents, (2) the stage of digestion which has been reached, (3) the degree of development and power of the muscular walls, and (4) the condition of the adjacent intestines. It is never entirely empty but always contains a few cc. of gastric fluid and mucin. When contracted the shape of the stomach is comparable to a sickle or sausage. At an early stage of gastric digestion, the stomach usually consists of two segments, a large globular portion on the left, and a narrow tubular portion on the right.

The stomach presents two openings and two borders or curvatures.

Openings.—The opening by which the esophagus communicates with the stomach is known as the cardiac or esophageal orifice, and the orifice which communicates with the duodenum is known as the pyloric. Both the cardiac and pyloric apertures are guarded by ring-like muscles known as sphincters which when contracted keep the orifices closed. They are contracted except when food is passing through them. By this arrangement, the food is kept in the stomach until it is ready for intestinal digestion, when the circular fibers guarding the pyloric aperture relax. The acidity of the stomach contents seem to produce this relaxation.

Curvatures.—In all positions the stomach is more or less curved upon itself. A line drawn from the cardiac orifice along the concave border to the pyloric orifice is said to follow the lesser curvature. A much longer line connecting the same points, but following the convex border defines the greater curvature.

Component parts.—The fundus is the blind rounded end of the stomach to the left of the heart. The opposite or smaller end is called the pyloric extremity and lies under the liver. The central portion between the fundus and pyloric extremity is called the intermediate region.

STRUCTURE.—The walls of the stomach consist of four coats: (1) serous, (2) muscular, (3) submucous or areolar, and (4) mucous.

NERVES AND BLOOD-VESSELS.—The stomach is supplied with nerves from the sympathetic system, and also with afferent and efferent branches from the vagus nerve. Stimulation of the vagus fibers increases secretion and peristalsis. Stimulation of the sympathetic fibers has just the opposite effect, i.e., inhibits secretion and peristalsis. The blood-vessels are derived from the three divisions of the celiac axis, i.e., gastric, and branches of the hepatic and splenic,

FUNCTIONS.--The functions of the stomach are (1) to connect the esophagus with the intestine. (2) To receive the food in relatively large quantities, say about three times a day, hold it while it undergoes certain mechanical and chemical changes, then pass it on to the intestine in small portions at frequent intervals. (3) To secrete mucin and gastric fluid.

THE SMALL, OR THIN, INTESTINE

The small intestine extends from the stomach (pyloric valve) above to the large intestine (ileocecal valve) below. It is a convoluted tube about twenty feet (6 m.) in length, and fills the greater part of the front abdominal cavity. Its diameter at the beginning is about two inches (5 cm.) but it gradually diminishes in size and is hardly an inch (2.5 cm.) in diameter at its lower end. The small intestine is divided by anatomists into three portions:--the duodenum, jejunum and ileum--but they are all continuous and show only slight variations.

THE DUODENUM.--The duodenum is twelve fingers' breadth in length (ten inches or 25 cm.), and is the shortest and broadest part of the small intestine. It extends from the pyloric end of the stomach to the jejunum.

THE JEJUNUM.--The jejunum or empty intestine, so called because it is always found empty after death, constitutes about two-fifths of the remainder, or seven and a half feet (2.2m.) of the small intestine, and extends from the duodenum to the ileum.

THE ILEUM.--The ileum, or twisted intestine, so called from its numerous coils, constitutes the remainder of the small intestine, and extends from the jejunum to the large intestine, which it joins at a right angle. The orifice is guarded by a sphincter muscle which acts as a valve, and prevents the return of material that has been discharged into the large bowel. This is known as the ileocecal shpincter or valve.

There is no definite landmark to determine the point at which the jejunum ceases and the ileum begins, although the mucous membrane of the one differs somewhat from the mucous membrane of the other; the change is a gradual transition, and one structure shades off into the other. The lengths in feet as given are arbitrary, but those usually accepted.

COATS OF THE SMALL INTESTINE.--The small intestine has four coats, which correspond in character and arrangement with those of the stomach.

(1) The SEROUS coat furnished by the peritoneum forms an almost complete covering for the whole tube except for part for the duodenum.

(2) The MUSCULAR coat of the small intestine has only two layers; an outer, thinner and longitudinal; and inner, thicker and circular. This arrangement aids the peristaltic action of the intestine.

(3) The SUBMUCOUS, or areolar coat connects the muscular and mucous coats.

(4) The MUCOUS coat is thick and very vascular.

Valvulae conniventes.--About one or two inches beyond the pylorus the mucous and submucous coats of the small intestine are arranged in circular folds called valvulae conniventes. Some of these folds extend all the way around the circumference of the intestine; others extend only one-half or one-third of the way. Unlike the rugae of the stomach, the valvulae conniventes do not disappear when the intestine is distended. About the middle of the jejunum they begin to decrease in size, and in the lower part of the ileum they almost entirely disappear. The purpose of the valvulae conniventes is: (1) to prevent the food from passing through the intestines too quickly, and (2) to present a greater surface for the absorption of digested food.

Villi.--Throughout the whole length of the small intestine the mucous membrane presents a velvety appearance due to minute finger-like projections called villi. Each villi consists of a central lymph channel called a lacteal, surrounded by a network of blood capillaries, held together by lymphoid tissue. This is surrounded by a layer of columnar cells. After the food has been digested it passes into the capillaries and lacteals of the villi, so that this arrangement increases the surface for absorption.

FUNCTION.--It is in the small intestine that the greatest amount of digestion and absorption takes place. It receives the bile from the liver and the pancreatic fluid from the pancreas. The glands of the small intestine secrete the succus entericus. The valvulae conniventes delay the food so that it is more thoroughly subjected to the action of these digestive fluids; and being covered with villi they increase the surface for absorption. Some of the cells of the mucous membrane (particularly in the duodenum) secrete a substance known as prosecretin. When the acid chyme enters the intestine, prosecretin is changed to secretin, and carried by the blood to the liver, pancreas, and all parts of the intestine, stimulating them to secretory activity.

THE LARGE, OR THICK, INTESTINE

The largeness of the next division of the alimentary canal is in its width, not in its length; for it is only about five feet (1.5 m.) long, but is wider than the small intestine, being two and one-half inches (6.3 cm.) in its broadest part. It extends from the ileum to the anus.

Like the small intestine, it is divided into three parts: the cecum with the vermiform appendix, colon, and rectum.

THE CECUM.--The cecum (caecus, blind) is a large blind pouch at the commencement of the large intestine. The small intestine opens into the side wall of the large intestine about two and a half inches (6.3 cm.) above the commencement of the large intestine. This two and one-half inches of large intestine forms a cul-de-sac below the opening, and this cul-de-sac is called the cecum. The opening from the ileum into the large intestine is provided with two large projecting lips of mucous membrane which allow the passage of material into the large intestine, but effectually prevent the passage of material in the opposite direction. These mucous folds form what is known as the valve of the colon, or the ileocecal valve.

THE VERMIFORM APPENDIX is a narrow, wormlike tube about the diameter of an ordinary lead pencil, and from three to seven inches (7.5 to 17.5 cm.) long. It is attached to the lower end of the cecum, but its directions and relations are very variable. In a general way it may be said to be located in the right iliac region. The function of the appendix is not known. It is most fully developed in the young adult, and at this time is subject to inflammatory and gangrenous conditions commonly called appendicitis. The reasons for this are (1) its structure does not allow of ready drainage, (2) its blood-supply is limited, and its circulation is easily checked, because the vessels anastomose to a very limited extent, (3) in youth it contains a considerable amount of lymphoid tissue which unlike the lymph-nodes is specially prone to bacterial invasion.

THE COLON.--The colon, though one continuous tube, is subdivided into the ascending, transverse and descending colon, with the sigmoid flexure. The ascending portion ascends on the right side of the abdomen until it reaches the under surface of the liver, where it bends abruptly to the left (right colic or hepatic flexure), and is continued across the abdomen as the transverse colon until, reaching the left side, it curves beneath the lower end of the spleen (left colic or splenic flexure), and passes downward as the descending colon. Reaching the left iliac region on a level with the margin of the crest of the ileum, it makes a curve like the letter S -- hence its name of sigmoid flexure -- and finally ends in the rectum.

THE RECTUM.--The rectum is from six to eight inches (15 to 20 cm.) long; from its origin at the third sacral vertebra it descends along the curve of the sacrum and the coccyx, and finally bends sharply backward into the anal canal.

The anus is the aperture leading from the rectum to the exterior of the body. It is guarded by an internal

sphincter muscle of the involuntary type, and an external sphincter that is voluntary, but both are supplied with nerves from the central nervous system. Consequently it is kept closed except during defecation.

FUNCTIONS.--The functions of the large intestine are three: (1) The process of digestion is continued. This is due to the presence of bacteria, and to the digestive fluids with which the food becomes mixed in the small intestine. (2) The process of absorption is continued, and (2) the waste products are removed from the body.

ACCESSORY ORGANS OF DIGESTION

The accessory organs of digestion are: (1) the salivary glands, (2) the tongue, (3) the teeth, (4) the pancreas, and (5) the liver.

PANCREAS

The pancreas is an elongated organ, of a pinkish color, which lies in front of the first and second lumbar vertebrae and behind the stomach. It weighs between two and three ounces (60 to 90 grams), and is about six inches (15 cm.) long, two inches (5 cm.) wide, and one-half inch (1.25 cm.) thick. In shape it somewhat resembles a hammer, and is divided into head, body and tail. The right end, or head, is thicker and fills the curve of the duodenum, to which it is firmly attached. The left, free end is the tail, and reaches to the spleen. The intervening portion is the body. The pancreatic and common bile duct usually unite and enter by means of a common opening into the duodenum about three inches (7.5 cm.) below the pylorus. The short tube formed by the union of the two ducts is dilated into an ampulla, called the ampulla of vater. Sometimes the pancreatic duct and the common bile duct open separately into the duodenum, and there is frequently an accessory duct (duct of Santorini) which opens into the duodenum about an inch above the orifice of the main duct.

Islands of Langerhans.--Scattered throughout the pancreas are round or ovoid bodies known as the islands of Langerhans. Each island is about one twenty-fifth of an inch (1 mm.) in diameter and consists of a group of many-sided cells. They are surrounded by a rich capillary network. Their function is to furnish the internal secretion of the pancreas, which is insulin and without which diabetes results.

FUNCTION.--Two secretions are formed in the pancreas. (1) The pancreatic fluid, which is one of the most important of the digestive fluids, is an external secretion and is poured into the duodenum during intestinal digestion. (2) The secretion formed by the islands of Langerhans is an internal

secretion that is absorbed by the blood and carried to the tissues. This internal secretion aids in the oxidation of glucose by the tissue cells.

THE LIVER

The liver (hepar) is the largest gland in the body, weighing ordinarily from fifty to sixty ounces (1500 to 1800 grams). The liver measures eight to nine inches (20 to 22 cm.) from side to side, six to seven inches (15 to 17.5 cm.) from front to back, and four to five inches (10 to 12 cm.) from above downward in its thickest part. It is a reddish brown organ, placed directly below the diaphragm, in front of the right kidney, the pyloric end of the stomach, and the upper part of the ascending colon. The upper convex surface fits closely into the under surface of the diaphragm. The under concave surface of the organ fits over the right kidney, the upper portion of the ascending colon, and the pyloric end of the stomach. The number five prevails in the parts and appendages of the liver.

FUNCTIONS.—The liver may be compared to a wonderful laboratory, the most wonderful in the body. It has four important functions:—

1. Bile production.--The cells of the liver manufacture bile from the blood brought to them by the portal tube.

2. Glycogenic.—The cells of the liver take from the blood brought to them by the portal tube a substance called glucose, which is derived from the carbohydrates of our food. This is stored in the liver in the form of glycogen until such time as the body needs more glucose than the food furnishes. When such demand is made, the liver cells reconvert the glycogen into glucose and pour it into the circulation.

3. Secretory.—-It is assumed that the liver furnishes an internal secretion which helps to regulate the changing of glucose to glycogen and then to glucose again.

4. Protective.—Its protective function is exercised in three ways: (a) Many of the end-products of protein digestion cannot be eliminated until they are acted upon by the liver, and changed into other substances which the kidneys can eliminate, e.g., urea is made from some of these end-products brought by the blood to the liver. (b) It finishes the disintegration of the worn out erythrocytes, which process is commenced in the spleen. (c) It plays an important part in the clotting of the blood, because it gives rise to antithrombin.

5. Heat-conserving.--It is the chief heat-conserving organ in our body.

THE GALL-BLADDER.--The gall-bladder is a pear-shaped sac lodged in the gall-bladder fissure on the under surface of the liver, where it is held in place by connective tissue. It is about four inches (10 cm.) long, one inch (2.5 cm.) wide, and holds about twelve drachms (44 cc.). It is composed of three coats: (1) the inner one is mucous membrane, (2) the middle one is muscular and fibrous tissue, and (3) the outer one is serous membrane derived from the peritoneum. It is only occasionally that the peritoneum covers more than the under surface of the organ.

FUNCTION.--The gall-bladder serves as a reservoir for the bile. In the intervals between digestion, i.e., when the duodenum is empty, the sphincter guarding the bile-duct is contracted and the bile is held in the gall-bladder. It is thought that the acid chyme entering the duodenum relaxes the sphincter, and the gall-bladder contracts and forces out its contents, which pour into the duodenum.

DIGESTIVE PROCESSES

In a broad sense all the processes by which foods are rendered available to an organism are digestive processes. The word alimentation is often used to include the preparatory processes together with the digestive processes. In this sense, many industrial and domestic processes are in line with digestion and often initiate the task which the digestive organs complete. This is particularly true of cooking, for by it various chemical changes are brought to pass; such, for example, as changing starches into dextrins, partially splitting fats into glycerin and fatty acids, and changing some proteins to the first stages of their decomposition products. A second reason for classifying cooking as a digestive process is that the appearance, odor, and taste of food are improved, and these facts stimulate the end-organs of the special senses, causing a reflex stimulation of the digestive mechanisms. In a third way cooking may profoundly aid digestion by killing parasites or bacteria which otherwise would gain a foothold in the alimentary canal and thus modify or change digestive processes. It is usual to describe digestion within the body as consisting of two processes, i.e., mechanical and chemical.

Both the chemical and mechanical processes of digestion are controlled by the nervous system. Any severe strain or strong emotion which affects the nervous system unpleasantly, inhibits the secretion of the digestive fluids and interferes with digestion, often checking the appetite and even preventing the taking of food. On the other hand, pleasurable sensations aid digestion, hence the value of attractively served food, pleasant surroundings, and cheerful conversation.

MECHANICAL DEGESTION.--Mechanical digestion is effected by various physical processes that occur in the alimentary canal. It is to be considered as preliminary to the more important chemical digestion. It serves four important purposes: (1) in taking food in and moving it along through the alimentary canal just rapidly enough to allow the required chemical changes to take place in each part; (2) in lubricating the food by adding the mucin and water secreted by the glands of the alimentary canal; (3) in liquefying the food by mixing it with the various digestive fluids; and (4) in separating the food into small particles, thereby increasing the amount of surface to come in contact with the digestive fluids.

The mechanical processes consist of:

1. Mastication.
2. Deglutition or swallowing.
3. Peristaltic action of the esophagus.
4. Movements of the stomach.
5. Movements of the intestines,
6. Defecation.

CHEMICAL DIGESTION.--The most essential part of digestion is chemical and is a process of hydrolysis which is dependent upon the presence of enzymes. The term hydrolysis means the breaking down of complex molecules into simpler ones with the absorption of water. An example of hydrolysis is the conversion of any of the complex sugars into simpler sugars. Thus the digestion of disaccharids (sugars) involves many splittings, but the process is always hydrolysis.

Necessity for Chemical Digestion.--Chemical digestion is necessary because foods, with the exception of simple sugars, cannot diffuse through animal membranes, and even if diffusion were possible, the tissues could not use them, hence they must be reduced to smaller molecules and to such standard substances as the tissues can use, i.e., (1) simple sugars, resulting from the digestion of all carbohydrates; (2) glycerin and fatty acids, resulting from the digestion of fats; and (3) amino-acids, resulting from the digestion of proteins.

Cause of Chemical Digestion.--It is possible to make carbohydrates, fats, and proteins undergo the same changes outside the body as occur during digestion. Carbohydrates, fats, and proteins, if boiled with a mineral acid or subjected to the action of enzymes, will hydrolyze and split up into simpler substances. Within the body these changes take place at body temperature, and are due to the enzymes present in all of the digestive fluids.

Enzymes.--Enzymes are organic substances which vary (hasten or retard) the speed of reactions, but do not initiate them. A distinction is frequently made between endoenzymes and exoenzymes. By endoenzymes is meant a

group of intracellular enzymes which are held within the cells in some form of combination. Exoenzymes include the group of enzymes which are eliminated from the cells in which they are formed, and are found in the secretions, for example, the ptyalin of the saliva, or the pepsin of the gastric fluid.

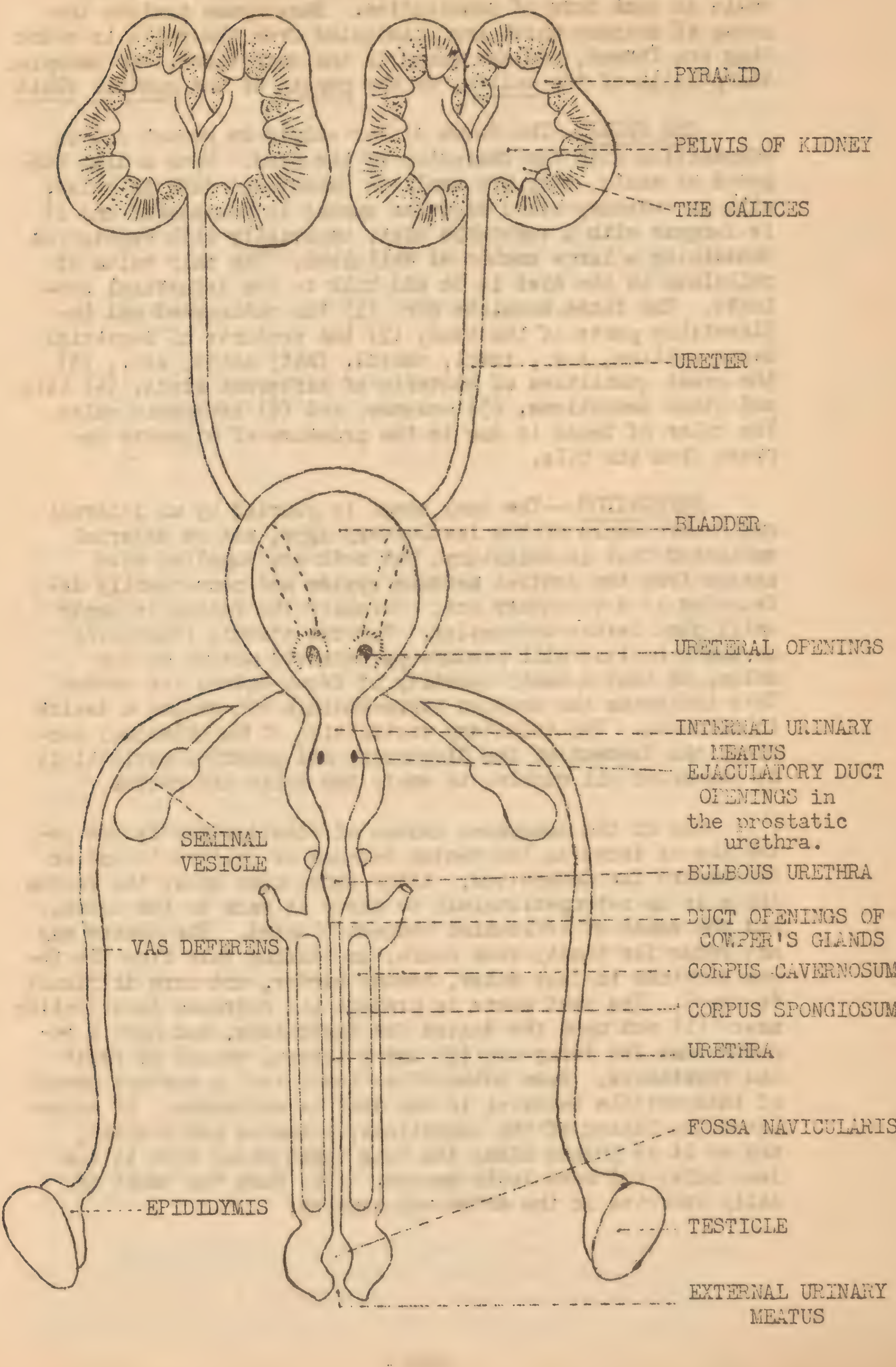
THE FECES.--The feces differ widely in amount and in composition with the character of the food. Upon a diet composed of meats, they are small in amount and dark in color; with an ordinary mixed diet the amount is increased; and it is largest with a vegetable diet, especially with vegetables containing a large amount of cellulose. The only value of cellulose in the diet is to add bulk to the intestinal contents. The feces consists of: (1) the undigested and indigestible parts of the food, (2) the products of bacterial decomposition, i.e., indol, skatol, fatty acids, etc., (3) the great quantities of bacteria of different kinds, (4) bile and other secretions, (5) enzymes, and (6) inorganic salts. The color of feces is due to the presence of pigments derived from the bile.

DEFECATION.--The anal canal is guarded by an internal sphincter muscle of the involuntary type, and an external sphincter that is voluntary, but both are supplied with nerves from the central nervous system and consequently defecation is a voluntary act. Normally the rectum is empty until just before defecation. Various stimuli (depending on one's habits) will produce peristaltic action of the colon, so that a small quantity of feces enters the rectum. This irritates the sensory nerve-endings and causes a desire to defecate. The voluntary contraction of the abdominal muccles, the descent of the diaphragm, and powerful peristalsis of the colon all combine to empty the colon and rectum.

One of the commonest causes of constipation is the retention of feces in the rectum because of failure to act on the desire for defecation. After feces once enter the rectum there is no retroperistalsis to carry it back to the colon, and the sense of irritation becomes blunted. The desire may not recur for twenty-four hours, and during this time the feces continue to lose water, become harder, and more difficult to expel. The best means to prevent and overcome constipation are: (1) act upon the desire for defecation, and have a regular time for doing so; (2) use a liberal amount of fruit and vegetables. Some authorities teach that a certain amount of indigestible material in the diet is wholesome. It stimulates the lining of the intestines, promotes peristalsis, and as it is pushed along the tube takes along with it the less bulky but more toxic wastes. (3) Form the habit of daily exercise in the abdominal muscles.

MALE GENITO-URINARY SYSTEM

-Fig 9-



CHAPTER SEVEN

THE GENITO-URINARY SYSTEM

A. THE EXCRETORY SYSTEM
B. THE REPRODUCTIVE SYSTEM

THE EXCRETORY SYSTEM

We have seen that the blood is constantly supplied by means of the respiratory and digestive mechanisms with all the chemical substances it requires to maintain the life, growth and activity of the body. These substances, entering the current of the blood, are carried to all the cells and are constantly combining with the chemical substances of which these cells are composed. One of the results of these chemical combinations are the formation of waste products, which must be removed from the body, as many of them are toxic.

WASTE PRODUCTS

The wastes of cell metabolism may be listed as follows:

1. Soluble Salts. { Nitrogenous salts, e.g., urea. / Inorganic salts, e.g., sodium chloride.
2. Liquid--Water.
3. Gas—Carbon Dioxide.
4. Solids—Waste materials from foods.

These wastes are classed as excreta and the process by which they are removed from the body as excretion or elimination.

EXCRETORY ORGANS

The organs that function as excretory organs and the products that they eliminate may be tabulated as follows:--

	ESENTIAL	INCIDENTAL
Lungs	Carbon dioxide,	Water.
Kidneys	Water & Soluble salts, resulting from metabolism of proteins, nuetralization of acids, etc.	Carbon dioxide,
Alimentary Canal	Solids,	Water, Carbon dioxide, salts.

In this chapter, we devote ourselves to the consideration of the urinary system, which consists of the following organs:--See Figure 9.

KIDNEYS, which form the urine from materials taken from the blood.

URETERS, ducts which convey the urine away from the kidneys.

BLADDER, a reservoir for the reception of urine.

URETHRA, a tube through which the urine passes from the bladder and is finally voided.

KIDNEYS

The kidneys are two compound tubular glands, placed at the back of the abdominal cavity, one on each side of the spinal column and behind the peritoneal cavity. They correspond in position to the space included between the upper border of the twelfth thoracic and the third lumbar vertebrae. The right is a little lower than the left in consequence of the large space occupied by the liver.

CAPSULE AND SUPPORTS.--The kidneys are covered by a thin but rather tough envelope of fibrous tissue called the capsule, the inner surface of which is slightly attached to the substance of the kidney by means of fine fibers and blood-vessels. The kidneys are usually embedded in a mass of fatty tissue termed the perirenal fat, and are not held in place by any distinct ligaments, but rather by fatty tissue and the pressure and counter-pressure exerted upon them by neighboring organs.

SIZE AND SHAPE.--Each kidney is about four and one-half inches (11.2 cm.) long, two and one-half inches (6.2 cm.) broad, one and one-half inches (3.7 cm.) thick, and weighs about four and one-half ounces (135 gm.). They are bean-shaped, with the concave side turned toward the spine, and the convex side directed outward. Near the center of the concave side is a depression called the hilum, which serves as a passageway for the ureter, and for the blood-vessels, lymph-vessels, and nerves going to and from the kidney.

ANATOMY OF THE KIDNEY.--If a kidney is cut in two lengthwise, it is seen that the upper end of the ureter expands into a basin-like cavity, called the pelvis of the kidney. This pelvis is irregularly subdivided into smaller, cup-like cavities, called calyces, which receive the pointed projections of the kidney substance.

The substance of the kidney is readily seen by the naked eye to consist of two distinct parts: (1) an outer, and more solid portion, called the cortex (bark); and (2) an inner,

striated portion, called the medulla (marrow), which is not a solid mass, but more or less distinctly divided into pyramidal-shaped sections. The cortical substance penetrates for a variable distance between the pyramids, separating and supporting them. The bulk of the kidney substance, both in the cortex and medulla, is composed of little tubes or tubules, closely packed together, having only just enough connective tissue to carry a large supply of blood-vessels and a certain number of lymphatics and nerves.

URINIFEROUS TUBULES.—Examined under the microscope, it is seen that the uriniferous tubules begin as little hollow globes, called the capsules of Bowman, in the cortex of the kidney. These capsules are joined to the tubules by a constricted neck, and the tubules, after running a very irregular course, open into straight collecting tubes, which pour their contents through their openings in the pointed ends or papillae of the pyramids, into the calyces of the kidney.

The tubules are composed of basement membrane, lined throughout by epithelial cells. The cells vary in the different parts of a tubule, those of the capsule and convoluted or irregular parts being more especially adapted to secretory purposes than the straight parts of the tubule.

PYRAMID.—These collecting tubules en masse, together with interstitial tissue, blood-vessels, and lymphatics, make a pyramid. The number of pyramids varies.

RENAL OR MALPIGHIAN CORPUSCLES.—In the cortical portion of the kidney are found renal corpuscles which consist of two parts: (1) a minute tuft of capillaries called a glomerulus, surrounded by (2) a closed capsule, called the capsule of Bowman, which is the beginning of a uriniferous tubule. The investment of the glomerulus by the capsule is double and complete except at one point, where an afferent vessel enters and an efferent vessel leaves.

THE BLOOD-SUPPLY OF THE KIDNEY.—For its size, the kidney is abundantly supplied with blood. The renal artery, coming directly from the aorta, divides, before it enters the hilus of the kidney, into several branches, which pass into the tissue of the organ. Branches from these arteries have two destinations: (1) into the cortex, and (2) into the pyramids.

FUNCTION OF THE KIDNEYS.—The function of the kidneys is to separate the constituents of urine from the blood, and thus help to maintain its normal composition. The kidneys extract almost all the protein waste, the greater part of the salts not needed by the blood, and about half of the excess water. The amount of water removed from the body by the kidneys varies considerably and is chiefly dependent upon the activity of the sweat-glands. The kidneys also

extract foreign substances, such as toxins, whether formed in the body, or taken into the body from outside. The concentration of urine, and not the quantity, is our criterion for judging the amount of work done by the kidneys. It is probable that they are most severely taxed when they have to remove from the blood the maximum of dissolved solids in a minimum of water.

THE SECRETION OF URINE.--The exact way in which the kidneys separate the urine from the blood is not known, but it is thought to be a double process, being partially accomplished by a mechanical filtration and partially by secretion due to the selective action of the cells lining the tubules.

The secretion of urine is a constant process. As previously stated, the blood-pressure in the renal vessels, and the velocity of the flow through these vessels, affects the secretion. Blood-pressure in the renal vessels is usually increased by (1) ingestion of water; (2) contraction of the blood-vessels in other parts of the body which drives more blood to the kidneys. This may be (a) contraction of the blood-vessels in the superficial parts of the body caused by chilling the surface and in other ways, or (b) contraction of the visceral blood-vessels under the influence of the sympathetic nervous system stimulated by various emotional states, nervousness, worry, fright, etc. (3) It is thought that the secretory activity of the cells of the tubule is stimulated by the urea content of the blood, as well as other waste products and foreign substances. This is comparable to the stimulation of the cells of other glands, by materials needed for their secretions, and like the latter the kidney cells abstract the material affecting them from the blood. Foreign substances in the blood stimulate the renal cells to increased activity.

Diuretics is the name given to drugs which stimulate the activity of the renal cells, and diuresis is the term applied to the increased secretion of urine. When the increase is marked and long-continued, it is called polyuria.

THE URETERS

The ureters are the excretory ducts of the kidneys. They consist of a distended portion called the pelvis, which is contained within the kidney, and a duct. Each duct is about the diameter of a goosequill, and from ten to twelve inches (25 to 30 cm.) long. They consist of three coats: an outer fibrous coat, a middle muscular, and an inner mucous lining which is continuous above with that of the pelvis of the kidney, and below that of the bladder.

FUNCTION.--The ureters connect the kidneys with the bladder and serve as a passageway to convey urine from the kidneys to the bladder.

The bladder is a hollow muscular organ situated in the pelvic cavity behind the pubes, in front of the rectum in the male, and in front of the anterior wall of the vagina, and the neck of the uterus, in the female. It is a freely movable organ, but is held in position by folds of peritoneum and fascia. During infancy it is conical in shape and projects above the upper border of the pubes into the hypogastric region. In the adult, when quite empty, it is placed deeply in the pelvis; when slightly distended, it has a round form; but when greatly distended, it is ovoid in shape and rises to a considerable height in the abdominal cavity. It is customary to speak of the widest part as the fundus, and the part where the bladder becomes continuous with the urethra as the neck, or cervix. It has four coats:--

1. The SEROUS coat is a reflection of the peritoneum, and only covers the upper portion of the fundus.

2. The MUSCULAR coat has three layers, an inner longitudinal, middle circular, and outer longitudinal. The circular fibers are collected into a layer of some thickness around the cervix or neck, where the bladder becomes continuous with the urethra. These circular fibers around the neck formaa sphincter muscle which is normally in a state of contraction, only relaxing at intervals, when the accumulation of urine within the bladder renders its expulsion necessary.

3. The AREOLAR coat connects the mucous and muscular.

4. The MUCOUS membrane lining the bladder is continuous with that of the ureters and the urethra.

There are three openings into the bladder, two at the upper part of the fundus--one on each side connecting with the ureters, and the third in the lower part of the cervix connects with the urethra.

FUNCTION.--The bladder serves as a reservoir for the reception of urine. When moderately distended, it holds about one pint (about one-half liter). The urethra is a narrow membranous canal which extends from the neck of the bladder to the external orifice which is named the meatus urinarius. Its normal diameter is about one-quarter of an inch (6.3 mm.) but it admits of considerable dilatation. Its length is about an inch and a half (3.8 cm.) in the female, and nine inches (22.5 cm.) in the male. In the female the urethra is placed behind the symphysis pubis, and is embedded in the anterior wall of the vagina. Its direction is obliquely downward and forward, its course being slightly curved, with the concavity directed forward and upward. Its external orifice is the narrowest part and is located between the clitoris and the opening of the vagina.

The wall of the urethra consists of three coats, an outer coat (muscular), a submucous coat, and inner coat which is continuous with that of the bladder.

MICTURITION

Urine is secreted continuously by the kidneys. It is carried to the bladder by the ureters and at intervals is expelled from the bladder through the urethra. The act by which the urine is expelled is called micturition. As a rule no stimulus is evoked to give rise to the desire to urinate until the bladder contains about $7\frac{1}{2}$ ounces (225 cc.). This accumulation stimulates the muscular walls to contract, and the resistance of the sphincter at the neck of the bladder is overcome. In theory micturition is a reflex act, but in practice it is a voluntary act.

INVOLUNTARY MICTURITION.—Involuntary micturition may occur as the result of lack of consciousness, and as the result of spinal injury involving the nerve centers which send nerves of control to the bladder. It may be due to a want of tone in the muscular walls, or it may result from some abnormal irritation due to irritant substances in the urine, or to disease of the bladder (cystitis). Excessive nervousness may provoke the desire to urinate when there is only a small amount of urine in the bladder. This desire may also be aroused by visual and auditory impressions such as the sight and sound of running water.

RETENTION OF URINE.—Retention or failure to void urine may be due to: (1) some obstruction in the urethra or in the neck of the bladder, (2) nervous contraction of the urethra, and (3) dulling of the senses so that there is no desire to void. In the last two conditions retention is often overcome by measures which induce reflexes, i.e., pouring water over the vulva, or the sound of running water. If micturition does not occur, and the bladder is not catheterized, distention of the organ may become extreme, and there is likely to be constant leakage, or voluntary voiding of small amounts of urine without emptying the bladder. These conditions are described as retention with overflow.

SUPPRESSION OF URINE.—A far more serious condition than retention is the failure of the kidneys to secrete urine. This is spoken of as suppression or anuria. This may occur when the blood-vessels are much relaxed as in shock. Unless suppression is relieved a toxic condition known as uremia will develop and this, unless the suppression is overcome, will be followed by death. When the secretion of urine is decreased below the normal amount the condition is spoken of as oliguria.

THE URINE

Normal urine may be described as a transparent, amber-colored liquid, with a characteristic odor, an acid reaction

when tested with litmus paper, and a specific gravity of about 1.020.

COMPOSITION OF URINE

The composition of urine is very complex; even in health it varies, depending on the kind and quantity of food eaten, etc. It is not difficult to understand this complexity when one recalls that the kidneys eliminate some of all the end-products resulting from food metabolism, together with the products of bacterial fermentation in the stomach and intestines.

ABNORMAL CONSTITUENTS.—The chief abnormal constituents that are liable to appear in the urine are albumin, glucose, indican, acetone, casts, calculi, pus, and blood.

Albumin.—Albumin is a normal constituent of the blood, but usually the kidney cells do not allow it to pass into the tubules. Certain conditions favor the excretion of albumin. These are: (1) increased blood-pressure in the renal vessels, (2) excessive amounts of protein food in the diet, (3) nervous conditions, (4) irritation of the kidneys, and (5) abnormal conditions of the kidneys.

Glucose.—Normal urine contains no sugars, or so little that for clinical purposes it may be considered absent. In health the amount of glucose present in the blood varies from 0.1 to 0.15 per cent. A higher per cent is irritating to the tissues, so when the quantity of sugar eaten is greater than the system can promptly change to glycogen and fat, the kidneys secrete and excrete it. When glucose is found in the urine from this cause, it is called temporary glycosuria. Temporary glycosuria frequently follows an injury to the head, or occurs during convalescence from fevers. In these cases it is thought to be due to temporary inability of the system to oxidize sugar. In the disease called diabetes mellitus, glucose persists in the urine. In mild cases this condition can be controlled by lessening the amount of carbohydrate food, but in severe cases glucose will appear in the urine even when no carbohydrates are eaten. This condition is serious because it means that the body tissues are being oxidized to form glucose.

Indican.—Indican is a potassium salt that is formed from indol. Indol results from the putrefaction of protein food in the large intestine. It is absorbed by the blood and carried to the liver, which it is thought changes the indol to indican, a less poisonous substance. Traces of indican are found in normal urine, but the presence of it in any amount is abnormal and may denote: (1) excessive putrefaction of protein food in the intestines or (2) disease of the stomach. (1) Excessive putrefaction may be due to a diseased condition of the intestine that interferes with absorption,

to a diet containing too much protein food, or to constipation. (2) In certain diseases of the stomach, food is held until it undergoes fermentative changes.

Acetone.—Acetone is a volatile substance that is thought to be the result of incomplete oxidation of fats and possibly of proteins. It is found in the urine of individuals suffering from defective metabolism, and in the urine of normal individuals during periods of fasting.

Casts.--In some abnormal conditions the kidney tubules become lined with substances which harden and form a mould or cast inside the tube. Later these casts are washed out by the urine, and their presence in urine can be detected by the aid of a microscope. They are named either from the substances composing them or from their appearance. Thus there are (1) pus casts, (2) blood casts, (3) epithelial casts from the walls of the tubes, (4) granular casts from cells which have decomposed and form masses of granules, (5) fatty casts from cells which have become fatty, and (6) hyaline casts which are formed from coagulable elements of the blood.

Calculi.—Deposits of solid matter that have been precipitated from the urine are called urinary calculi or stones. These vary in size, shape, and composition; the size and shape being determined largely by their composition and location; they may be formed in any part of the urinary tract from the tubules to the external orifice of the urethra. The causes which lead to their formation are (1) an increase in the slightly soluble constituents of the urine, (2) a decrease in the amount of water secreted, and (3) abnormally acid or abnormally alkaline urine.

Pus.--In suppurative conditions of any of the urinary organs pus cells are present in the urine.

Blood.--In cases of acute inflammation of any of the urinary organs, of tuberculosis, of cancer, and of renal stone, blood may be found in the urine. If present in large quantities, the urine is deep red, and the condition is known as hematuria.

THE MALE REPRODUCTIVE SYSTEM

ESSENTIAL	ACCESSORY
Testes or Testicles which produce the spermatozoa, and the internal secretion.	2 Vas Deferens. 2 Seminal Vesicles. 2 Ejaculatory ducts. 2 Spermatic Cords. 1 Scrotum. 1 Penis and urethra. 1 Prostate gland. 2 Cowper's gland.

TESTES.—The testes are two glandular organs which are suspended from the inguinal region by the spermatic cords, and are surrounded and supported by the scrotum. Each gland weighs from six to eight drachms (22 to 30 gms.) and consists of two portions: (1) the testicle proper, and (2) the epididymis.

The epididymis is a long, narrow body, which lies along the upper posterior portions of the testicle and consists of a tortuous tubule, which is lined with mucous membrane, and contains some muscular tissue in its walls. If unravelled it is found to be about twenty feet (5 meters) long. It connects the testicle proper with the vas deferens.

FUNCTION.--The function of the testes is the production of spermatozoa, and an internal secretion (hormone) which influences the development of the secondary sex characteristics of the male. The reason for this belief is that if the testes are removed before puberty, the boy remains undeveloped, the enlargement of the larynx does not occur, there is no growth of hair on the face, and the features are infantile. The thymus, pituitary and cortex of the adrenals are increased, but the growth of the thyroid is diminished, and mental development tends to be retarded.

Descent of the testes.--In early fetal life the testes are abdominal organs lying in front of and below the kidneys. During the process of growth they are drawn downward through the inguinal canal and shortly before birth are normally found in the scrotum. Sometimes, particularly in premature infants, a testis is found in the inguinal canal or even in the abdominal cavity; as a rule it soon descends and occupies its proper position; but occasionally it does not descend and an operation is necessary.

VASA DEFERENS (Seminal duct).--Each duct is a continuation of the epididymis, and is the excretory duct of the testicle. After a very devious course it reaches the prostate gland, which lies in front of the neck of the bladder. Here each duct ends by joining the duct from the corresponding seminal vesicle to form one of the ejaculatory ducts. Each consists of three coats, an external areolar, a middle muscular, and an internal mucous coat.

THE SEMINAL VESICLES.--The seminal vesicles are two sac-like organs which are placed on the outer side of each vas deferens, between the bladder and the rectum. They are pyramidal in form, with the broad ends directed backward and widely separated. The anterior portions converge, become narrowed, and unite on either side with the corresponding vas deferens to form the ejaculatory duct.

FUNCTION.--The seminal vesicles serve as reservoirs for the semen, to which they add a secretion of their own.

THE EJACULATORY DUCTS.--The ejaculatory ducts are two in number, one right and the other left. They are formed by the union of the seminal vesicle and descend, one on each side, and passing between the lobes of the prostate gland, finally reach the urethra into which they open and discharge their contents. Each has an external areolar, middle muscular, and internal mucous coat.

THE SPERMATIC CORDS.--Each cord consists of a seminal duct, an artery, veins, lymphatics, nerves, and connecting areolar tissue covered with fascia that is continuous with that covering the testes. These structures come together and form a cord just above the internal abdominal ring, through which the cord passes, and descends into the scrotum where it connects with the posterior surface of the testes.

THE SCROTUM.--The scrotum is a pouch consisting of (1) a layer of thin relatively dark skin, disposed in folds or rugae and in the adult covered with short hairs; and (2) the dartos tissue made of elastic tissue, plain muscular tissue, and numerous blood-vessels. The dartos send in a fold of tissue which serves as a partition dividing the interior of the scrotum into two chambers, and separating the testes. The tissues of the scrotum are continuous with those of the groin and the perineum. The scrotum contains and supports the testes, and the lower part of the spermatic cords.

THE PENIS.--The penis is an organ attached above to the symphysis pubis and suspended in front of the scrotum. It is composed of three cylindrical masses of cavernous tissue bound together by fibrous tissue and covered with skin. Two of the masses are lateral and are known as the corpora cavernosa penis; the third is median and is termed the corpus cavernosum urethrae because it contains the urethra. The term cavernous tissue is used because of the relatively large size of the venous spaces which exist in this tissue. It is also described as erectile tissue because the venous spaces may become distended with blood, thus enlarging the tissue and increasing its turgidity. The skin covering the penis is continuous with that covering the scrotum, the perineum, and the pubes. At the end of the penis there is a slight enlargement known as the glans penis, in which the urethral orifice is situated. In that region of the glans, the loose integument of the penis becomes folded inward, and then backward upon itself forming the prepuce or foreskin. Sometimes this foreskin covers the glans too tightly. This conditionsis known as phimosis.

The urethra extends from the bladder through the corpus cavernosum urethrae to the end of the penis. The length is usually given as nine inches (22.5 cm.), a large part of which lies in the pelvis. It is lined with mucous membrane and furnished with numerous muscular fibers.

THE PROSTATE.--The prostate gland is situated in front of the neck of the bladder and around the commencement of the urethra. It resembles a chestnut in form and consists of a dense fibrous capsule containing glandular and muscular tissue. The glandular tissue consists of tubules which communicate with the urethra by minute orifices.

FUNCTION.--The function of the prostate gland is to secrete the prostatic fluid, which is an essential element of the seminal fluid. It gives motility to the spermatozoa.

COWPER'S GLANDS.--These are two small bodies about the size of a pea situated one at each side of the prostate gland. Each one is provided with a duct about 1 inch (2.5 cm.) in length which terminates in a minute orifice in the wall of the urethra. These glands secrete a viscid fluid, which goes to form part of the seminal fluid.

SEMEN.--The semen is a fluid derived from the various sexual glands in the male. The main elements in this fluid are the spermatozoa; the other constituents are derived from the seminal vesicles, prostate gland, and Cowper's glands.

THE FEMALE ORGANS OF REPRODUCTION

1. LABIA MAJORA AND MINORA - large and small lips. They are protective and sensory.

2. CLITORIS - a homologue of the penis, but in comparison is more richly supplied with nerves - Function: chiefly sensory.

3. VAGINA - the depository vault where from the semen travels up into the womb.

4. THE WOMB OR UTERUS.--the birth chamber wherein the fertilized ovum usually becomes entrenched and normally develops for nine months, obtaining nourishment and blood for growth from the mother through special vessels that develop in the walls of the uterus.

5. FALLOPIAN TUBES OR OVIDUCTS - are two tubes, homologous (similar in function to vas deferens in the male) that conduct the ovum, or female egg, from the ovary where it is developed and extruded, to the uterus. Fertilization of the ovum, by the spermat, takes place, as a rule, in these tubes, and takes about 9 days to complete the descent to the uterus.

6. OVARY - the ovaries are homologous to the testes, and like the testes have a dual function. They elaborate an internal secretion which largely is responsible for the female secondary characteristics, such as form, voice,

skin, hair, etc. They also produce, via the graafin follicles, the female eggs or ova. About once every 28 days in the average woman one of these eggs matures and is extruded from the ovary. If not fertilized by the male seed, they become part of the process known as menstruation. If fertilized by the male seed, it becomes the mother or chief unit of reproduction. The head and middle piece of the male seed enters the ovum via the germinal spot, whereas the tail, having served its purpose, is cast away at time of entry. The ovum is quite large as compared to the spermat, it being 1/125 (0.2 mm.) inch in diameter. It is estimated that about 35,000 ova are present in both ovaries of the average normal woman.

CHAPTER VIII

THE ENDOCRINE OR DUCTLESS GLANDS

The endocrine or ductless glands form a group of organs that produce secretions, called internal secretions, which leave the gland by the blood or lymph. Many of the glands that possess ducts and form an external secretion form an internal secretion as well, i.e., the liver and pancreas, but these are not classed as ductless, because the external secretion is carried out of the glands by means of a duct, though the internal secretion passes into the blood and lymph just as in the ductless glands. The function of the ductless glands is intimately connected with the purpose of the internal secretions, and this is imperfectly understood. Because it is difficult to secure internal secretion in a state of purity, i.e., without the lymph or blood into which it is poured, the methods of investigation have been: (1) observation of the conditions caused by disease of these glands; (2) various experiments on animals such as removing a gland and later transplanting a similar gland taken from another animal, or else injecting into the animal extracts prepared from the gland; (3) chemical examinations of the glands, or of its extracts, or of the blood which leaves it. In some cases removal of the gland is followed by disease and death indicating that the internal secretion produced is essential for life.

AUTACOIDS.--As a result of various investigations it has been determined that internal secretions contain substances which activate or depress the function they effect. These substances are called autacoids from two Greek words meaning natural remedy. The term is applied to any drug-like principle which is produced in the internal secreting tissues and organs. Those which activate functions are called hormones. But it must not be understood that hormones are found only in the internal secretions, because any chemical substance which is produced in an organ and on being carried by the blood to another organ or part stimulates activity, is a hormone. The carbon dioxide formed in the tissues (particularly in the muscles) acts as a hormone by stimulating the respiratory center in the medulla; the urea, the end-product of protein digestion, stimulates the kidneys.

The most important ductless glands are:

1. The Thyroid.
2. The Paratyphoids.
3. The Thymus.
4. The Suprarenal Capsules or Adrenals.
5. The Hypophysis or Pituitary body.
6. The Epiphysis or Pineal body.
7. The Testes.
8. The Ovaries.
9. The Placenta (during pregnancy).

Special cells in the pancreas and liver, also portions of the lining membrane of the stomach and intestines function as ductless glands, and furnish an internal secretion or endocrines to the products of the ductless glands.

(1) <u>The thyroid.</u>--The thyroid is a small, flat gland lying against the fore part of the trachea, below the thyroid cartilage. It is of a deep red color, weighs about an ounce (30 gms.), and consists of a right and left lobe placed on each side of the trachea. The lower parts are broader, and are connected by a strand of their own substance called the isthmus, which stretches across the front of the trachea. The glandular portion is enveloped by areolar tissue, which extends inward, dividing the substance into lobes and lobules, and gives off folds which bind the gland in place. Small masses of thyroid tissue are sometimes found along the trachea as far down as the heart. They are called <u>ACCESSORY THYROIDS</u>. The size of the thyroid varies with age, sex, and general nutrition, being relatively larger in youth, in women, and in the well-nourished. It increases in size temporarily during menstruation and pregnancy. Removal or disease of the thyroid resulting in an absence, decrease or increase of the internal secretion is followed by grave disturbances which are grouped under two headings, i.e., hypothyroidism, or lack of thyroid secretion, and hyperthyroidism, or excess of thyroid secretion.

<u>Function</u>.--Because of the marked conditions, resulting from an increase or decrease of the internal secretion, it is believed that the function of the thyroid is to secrete an active principle (hormone) that stimulates metabolism, and influences the development and activity of the nervous system. It is further believed that the efficacy of the secretion is due to thyroiodin, a substance containing a large percentage of iodine in its molecule,

<u>Goiter</u> is a condition in which the gland is enlarged, the secretion may or may not be affected in any way, though it often is.

<u>THE PARATHYROIDS.</u>--Embedded in the surface of each lateral lobe of the thyroid are two little masses, each about one-fourth inch (6.25 mm.) in diameter. They are solid accumulations of epithelial cells, invested with a tunic of areolar tissue and well supplied with blood-vessels. They are so intimately connected with the thyroid that it is difficult to study their function, but it is believed that the tetany and severe nervous symptoms resulting from atrophy or removal of the thyroid, are really due to the parathyroids. The parathyroids contain no iodine, and it is doubtful if they form an internal secretion. Their function is to neutralize poisonous substances, which result from interference with the metabolism of nucleoproteins.

THE THYMUS.—The general belief until the last few years has been that the thymus was a temporary organ attaining its greatest size soon after birth, and gradually diminishing after the second year. Recent studies indicate that the thymus persists longer, and may continue to grow until puberty, in fact, some true thymus tissue may persist through life. It is an irregular-shaped body containing glandular and lymphoid tissue. It is surrounded by a fibrous capsule, strands from which enter the organ, dividing into lobes, and serving as a support for the blood and lymph-vessels and nerves. It is situated in the center of the lower part of the neck, and the upper part of the mediastinum. The function of this gland and the nature of its secretion are unknown, except that it seems to aid metabolism, and have a retarding influence on the development of the male organs of generation. Removal of the thymus from small animals such as puppies hastens the growth of the testes. Removal of the testes (castration) retards the atrophy of the thymus.

THE SUPRARENAL CAPSULES OR ADRENALS.—They are small triangular-shaped bodies of a yellowish color, which are placed one above each kidney. They are surrounded by a capsule of fibrous tissue, and consist of two parts known as the cortex and medulla, which differ in structure and function. The medulla which is in the interior consists of a highly vascular mass of chromaphil substance, so called because the granules in its cells dye a deep yellow or brown when treated with chromic acid. This medullary portion secretes a substance called epinephrin. Under ordinary conditions only enough epinephrin is secreted to help maintain the tone of the blood-vessels, but when the adrenals are stimulated the amount of epinephrin discharged into the blood is increased, and stimulation of the sympathetic nervous system results. This effect is supposed to be due to stimulation of the myoneural connections, and the results are favorable for muscular activity, but unfavorable for digestion. Pain, fear, anger and excitement are common causes of sympathetic stimulation, and consequently of the secretion of epinephrin. The cells of the cortex differ from those of the medulla. Their function is unknown, but it is assumed that they form a secretion, the lack of which gives rise to the symptoms of Addison's disease. The symptoms are a pigmentation (bronzing) of the skin, great muscular weakness, loss of vascular tone, nervous prostration, and mental apathy. A connection between the suprarenals and the sex glands is suggested by the fact that during pregnancy they become enlarged, and in autopsies it has been found that if they are underdeveloped, the sex glands are overdeveloped, and if the sex glands have been removed, the cortex of the suprarenals is usually enlarged.

THE HYPOPHYSIS OR PITUITARY BODY.—The hypophysis is a small mass of reddish brown tissue about the size of a pea and consists of two lobes separated by a cleft-like space

called the pars intermedia which is filled with cells that secrete a glairy yellow fluid that passes into the ventricles of the brain. The anterior lobe is larger and distinctly glandular, the posterior lobe is smaller and consists chiefly of neuroglia. The hypophysis is situated at the base of the brain, lodged in a depression of the middle portion of the sphenoid bone, and firmly held in place by the dura mater.

From the results of various experiments it is evident that the hypophysis is essential to normal metabolism, and moreover that the anterior and posterior lobes exercise different functions.

The Posterior Lobe.--A substance called hypophysin or pituitrin is obtained from extracts of the posterior lobe. Intravenous injections of such extracts produce contraction of all the plain muscle tissue of the body, shown by (1) a rise in blood-pressure, due to constriction of the peripheral arterioles and a consequent slowing and strengthening of the pulse, (2) increased intestinal peristalsis, (3) contraction of the bladder and the pregnant uterus, (4) increased flow of some of the secretions, particularly the milk in nursing mothers, (5) a dilatation of the blood-vessels of the kidneys accompanied by pronounced diuresis. Because of these results it is assumed that the function of the posterior lobe is to help maintain the tone of plain muscular tissue, and to influence the activity of the kidneys. Removal of the posterior lobe does not cause death.

The anterior lobe.--The injection into the blood of extracts prepared from the anterior lobe has produced no effect, but removal of the entire lobe causes death at once. If only a portion is removed death does not always follow but the animals experimented upon revert to an infantile state. Gigantism or excessive growth, and dwarfism or underdevelopment are thought to be due, the first to enlargement and the second to underdevelopment or atrophy of the gland in early life. In later life enlargement produces the condition known as acromegaly. The symptoms of acromegaly are enlargement of the bones, increased production of connective tissue, and consequent distortion of the face; the mandible is especially enlarged, the eyelids thicken, the lips swell; the hands and feet grow abnormally large. There is loss of intelligence, and blindness is not uncommon, and may be due to pressure of the enlarged gland upon the brain.

THE EPIPHYSIS OR PINEAL BODY.--The epiphysis is a small reddish gray body that develops as an outgrowth of the third ventricle of the brain and remains attached to the roof of the ventricle. In early life it is glandular and attains its maximum growth about the seventh year. After this period,

and particularly after puberty, it decreases in size, and the glandular tissue is replaced by fibrous tissue. Its functions are not known, but it is thought that it secretes a hormone and a chalone that regulate the development of the sex organs.

THE LIVER AND THE PANCREAS.--The glucose brought to the liver by the portal blood is stored in the liver cells in the form of glycogen (animal starch), and when needed is again converted to glucose. Consequently it is assumed that the liver furnishes an internal secretion which helps to regulate these chemical changes. Likewise special groups of cells in the pancreas called the Islands of Langerhans furnish an internal secretion which changes the glucose of the blood into a form adapted to the chemical powers of the tissue cells. Glucose which has not been acted upon in this way cannot be oxidized, and consequently remains in the blood until eliminated by the kidneys. This metabolic disturbance is one of the fundamental causes of diabetes mellitus, and follows the destruction of the islands of Langerhans.

INTERNAL SECRETION OF THE OVARIES AND TESTES.--The ovaries, two of the female organs of generation, produce ova or cells from which new beings may develop and in addition produce two internal secretions. Apparently one secretion is formed by cells in the body of the ovary, and the other by cells known as the corpus luteum. It is believed that these secretions (1) stimulate the development of sexual characteristics including menstruation, and (2) aid metabolism. The placenta which develops during pregnancy secretes a hormone that checks the secretion of milk until after its expulsion at the time of birth. The testes, two of the male organs of generation, produce spermatozoa, one of which may unite with one of the ova to produce a new being. In addition they furnish an internal secretion which influences the development of sex characteristics in the male.

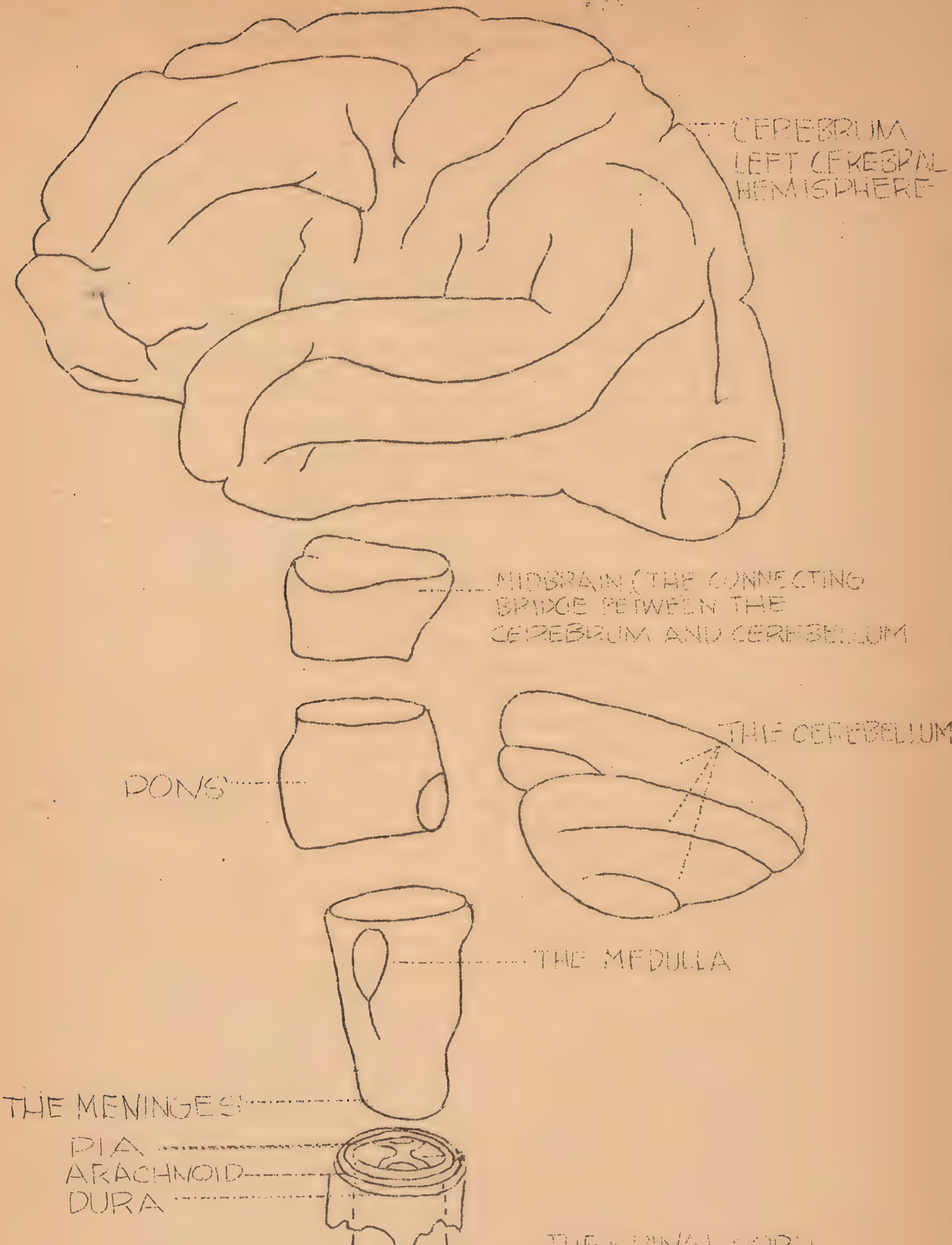


DIAGRAM OF CENTRAL NERVOUS SYSTEM

FIG. 10

CHAPTER IX

THE CENTRAL NERVOUS SYSTEM

THE BRAIN

The brain is the largest and most complex mass of nervous tissue in the body. It is contained in the cavity formed by the bones of the cranium, and comprises five fairly distinct, though connected parts: the cerebrum, the cerebellum, the mid-brain, the medulla oblongata, and the pons Varolii.

WEIGHT OF THE BRAIN.--With the exception of the whale and the elephant, the human brain is heavier than that of any other animal. The average weight of the brain in the male is 46.6 ounces avoirdupois (about 1400 gms.); in the female, 41 ounces avoirdupois (about 1240 gms.). The weight of the brain is an indication of growth, which in early life depends upon an increase in the number of cells and their processes. The brain grows rapidly up to the fifth year and ceases to grow generally in the eighteenth or twentieth year. After the sixtieth year the brain loses weight, at first slowly, later more rapidly.

DEVELOPMENT OF THE BRAIN.--The development of the brain is not entirely a matter of growth but rather a matter of forming new pathways, i.e., new connections between synapses, and a permanent modification of the synapses that are functionally active during various forms of mental activity. The nature of the brain protoplasm, and the use to which it is put determines to some extent the length of time during which development may continue. Mental exercise keeps the brain capable of development just as exercising a muscle tends to prevent atrophy, or loss of function.

CEREBRUM.--The cerebrum is by far the largest part of the brain. It is egg-shaped, or ovoidal, and fills the whole of the upper portion of the skull. The entire surface, both upper and under, is composed of layers of gray matter, and is called the cortex because, like the bark of a tree, it is on the outside. The bulk of the white matter in the interior of the cerebrum consists of very small fibers running in three principal directions: (1) from above downward, (2) from the front backward, and (3) from side to side. The fibers link the different parts of the brain together, and connect the brain with the spinal cord.

FISSURES AND CONVOLUTIONS.--In early life the cortex of the cerebrum is comparatively smooth, but as time passes and the brain develops, the surface becomes covered with depressions which vary in depth. The deeper depressions are called fissures, the more shallow ones, sulci, and the

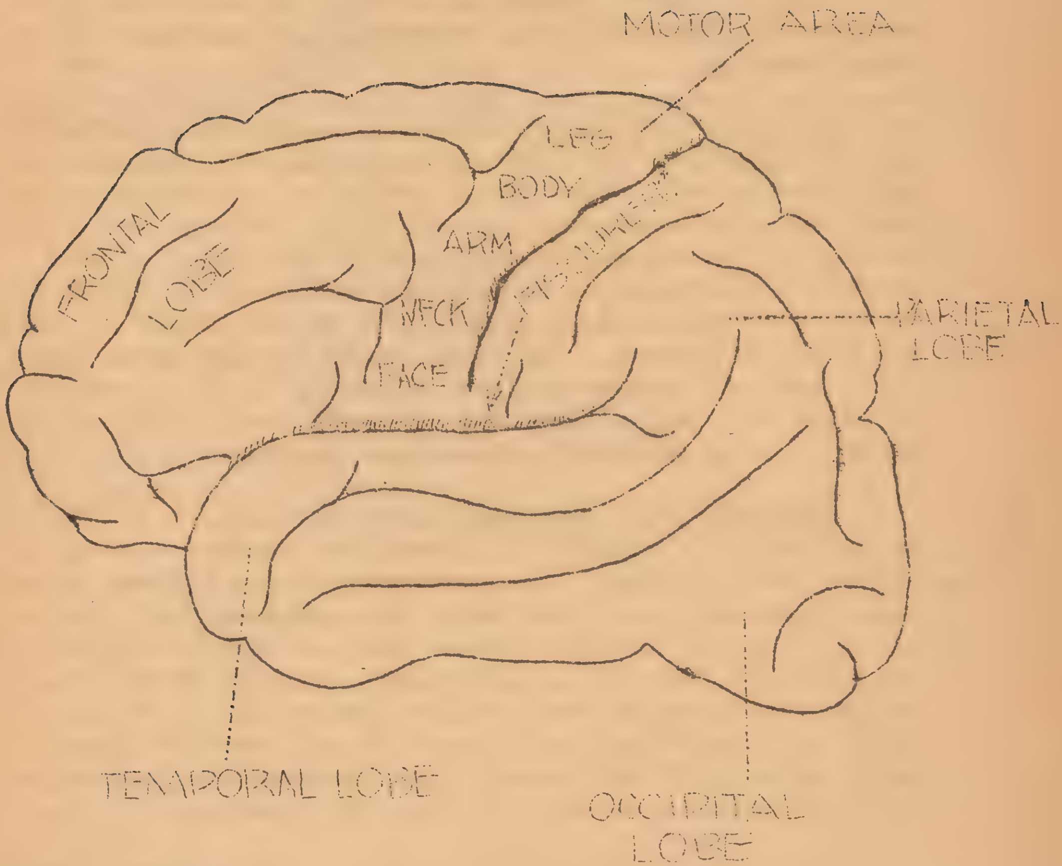


DIAGRAM OF CEREBRAL HEMISPHERE

FIG. 11

ridges between the sulci are called convolutions. The fissures and sulci are infoldings of gray matter, consequently the more numerous and deeper they are, the greater is the amount of gray matter. The number and depth of these fissures and sulci is thought to bear a close relation to intellectual power; babies and idiots have few and shallow folds, while the brains of men of intellect are always markedly convoluted.

LOBES OF THE CEREBRUM.—The longitudinal fissure divides the cerebrum into two hemispheres, and the transverse fissure divides the cerebrum from the cerebellum. The three remaining fissures divide each hemisphere into five lobes. With one exception these lobes were named from the bones of the cranium under which they lie; hence they are known as:—

(1) Frontal lobe.
(2) Parietal lobe.
(3) Temporal lobe.
(4) Occipital lobe.
(5) Central lobe, or Island of Reil (the exception). See Figure 11.

(1) The FRONTAL lobe is that portion of the cerebrum lying in front of the fissure of Rolando, and usually consists of four main convolutions.

(2) The PARIETAL lobe is bounded in front by the fissure of Rolando, and behind by the parieto-occipital fissure.

3. The TEMPORAL lobe lies below the fissure of Sylvius and in front of the occipital lobe.

(4) The OCCIPITAL lobe occupies the posterior extremity of the cerebral hemisphere. When one examines the external surface of the hemisphere, there is no marked separation of the occipital lobe from the parietal and temporal lobes that lie to the front; but when the surface of the longitudinal cleft is examined, the parieto-occipital fissure serves as a boundary anteriorly for the occipital lobe.

(5) The CENTRAL lobe, or Island of Reil, is not seen when the surface of the hemisphere is examined, for it lies within the fissure of Sylvius, and the overlying convolutions of the parietal and frontal lobes must be lifted up before the central lobe comes into view.

Ventricles of the brain.—The brain is not a solid mass, but contains cavities called ventricles. The two lateral ventricles, shaped like the italic F are situated one in each of the cerebral hemispheres under the mass of white fibers called the corpus callosum, which connects the two hemispheres.

FUNCTIONS OF THE CEREBRUM.—The nerve centers which govern all our mental activities, reason, intelligence, will, memory, and the higher emotions and feelings, are located in the cerebrum. It is the seat of consciousness, the interpreter of sensations, the instigator of voluntary acts, and exerts a controlling force both accelerating and inhibiting upon many reflex acts which originate as involuntary. Laughing, weeping, micturition, defecation and many other acts might be cited as examples of the latter.

LOCALIZATION OF BRAIN FUNCTION.—As the result of numerous experiments on animals, and close observation of individuals suffering from wounds or cerebral disease, physiologists have been able to localize certain areas in the brain which control motor and sensory activity. They have also been able to gain some knowledge of the areas in the cerebrum which are concerned with the higher mental activities. But in no case is the control of a function limited to a single center, for practically all mental processes involve the discharge of nervous energy from one center to another, and the recall of memories of former experiences.

NAMES OF AREAS.--That portion of the cerebrum which governs muscular movement is known as the motor area, the portions controlling sensation as the sensory areas, and those connected with the higher faculties, such as reason, and will, as association areas.

MOTOR AREAS.--The surface of the brain assigned to the function of motion is the posterior part of the frontal lobe, i.e., the gray matter immediately in front of the fissure of Rolando. The centers which govern skeletal muscles are controlled by nerves arising in this area, and the special portions of the area in which the nerves supplying the various parts arise, for example, tongue, mouth, fingers, leg (See Figure 11).

SENSE AREAS.—The term sense areas is used to designate those parts of the brain to which sensation is due, and which control vision, hearing, smell, taste, and to some extent, speech. The visual area is situated in the posterior part of the occipital lobe; the auditory area in the superior part of the temporal lobe; and the olfactory (smell) and gustatory (taste) areas are in the anterior part of the temporal lobe.

CEREBELLUM.—The cerebellum, or "little brain", occupies the lower and back part of the skull cavity. It is below the posterior portions of the cerebrum, and behind the pons and the upper part of the medulla. It is of a flattened, oblong shape, and measures from three and a half to four inches (8.7 to 10 cm.) transversely, and from

two to two and a half inches (5 to 6.3 cm.) from before backward.

The surface of the cerebellum consists of gray matter and is convoluted in much the same manner as the cortex of the cerebrum. The gray matter contains cells from which fibers pass from the cerebellum, and with which fibers entering the cerebellum from other parts of the brain form synapses. The cerebellum is connected with the cerebrum, pons Varolii, and medulla by bundles of fibers called peduncles which are arranged in three pairs. Incoming impulses from the motor centers in the cerebrum, from the semi-circular canals of the inner ear, and from the muscles, enter the cerebellum by way of these bundles. Outgoing impulses are transmitted to the motor centers in the cerebrum, down the cord, and thence to the muscles.

FUNCTIONS OF CEREBELLUM.--It is thought that the cerebellum assists in maintaining muscular tone, and is probably the chief center for the control of muscular coordination, and the maintenance of equilibrium. The reasons for these beliefs are that injury to the cerebellum results in muscular weakness, loss of tone, and inability to direct the movements of the skeletal muscles. There may be difficulty in walking due to inability to control the muscles of the legs, or difficulty in talking due to lack of coordination of the muscles moving the tongue and jaw. The area of the body affected is determined by the location and extent of the injury to the cerebrum. Only parts of the body on the same side as the injury to the cerebellum are involved, unless both sides of the cerebellum are injured, and then the lack of muscle tone and coordination may be so great that the person is helpless.

THE MID-BRAIN.--The mid-brain is a short constricted portion which connects the pons and cerebellum with the hemispheres of the cerebrum. It is directed upward and forward and consists of: (1) a pair of cylindrical bodies called the cerebral peduncles, (2) four rounded eminences called the corpora quadrigemina, and (3) an intervening passage or tunnel, the cerebral aqueduct (aqueduct of Sylvius) which serves as a communication between the third and fourth ventricle.

THE MEDULLA OBLONGATA.--The medulla oblongata, also known as the spinal bulb, is continuous with the spinal cord, which, on passing into the cranial cavity through the foramen magnum, widens into an oblong-shaped mass about one and a quarter inches long.

Decussation of nerves.--The fibers extending from the brain into the cord, and from the cord into the brain, decussate or cross in the medulla. Because of this it follows that the nerves arising in the cortex of the right

side govern the movements of the left side of the body, and vice versa.

In many cases of paralysis or convulsions, it is possible to locate the exact portion of the brain that is affected, by close observation of the part of the body involved in the loss of function or convulsion.

FUNCTIONS OF THE MEDULLA OBLONGATA.--The functions of the medulla are of such importance that it is capable of assuming through them a position almost independent of the cerebrum. The centers situated in the medulla are of two kinds: viz, simple reflex and dominating or automatic.

A. The reflex centers are:--

(1) The respiratory center for regulating the function of respiration.--The fibers from this center enter the gray matter of the cord, descend and form synapses with neurons that transmit impulses to the diaphragm and the chest muscles used in respiration. This center is automatic because it is constantly discharging impulses induced by internal stimulation; the carbon dioxide of the blood acting as a stimulus. It is also a reflex center because it responds to afferent impulses.

(2) The vasomotor center for regulating the tone of the blood-vessels. Functionally it may be regarded as consisting of a vaso-constrictor and vasodilator part, as the efferent or motor path is composed of two types of fibers, those which diminish and those which enlarge the lumen of the vessels.

(3) The cardiac accelerator center.--Fibers from this center pass by way of the cord and sympathetic ganglia to the heart, and carry impulses which increase the strength and rate of the heart's action.

(4) The cardiac inhibitory center.--The fibers of this center arise in the nucleus of the vagus and follow the pathway of this nerve to the heart. When they reach the heart they enter into relation with the cardiac plexus which envelops the ascending portion and arch of the aorta, and from here are distributed to the nerve centers in the heart as well as to the musculature. All in all it is one of the most widely connected structures of the nervous system, and if it is seriously injured, death will result.

THE MENINGES.--The brain and spinal cord are enclosed within three membranes. These are named from without inward: the dura mater, arachnoid, and pia mater (See Figure 10).

THE DURA MATER is a dense membrane of fibrous connective tissue containing a great many blood-vessels. It is arranged in two layers and the layers are attached except in a few places. The external layer is adherent to the bones of the skull, and forms their internal periosteum. The internal layer covers the brain and sends numerous prolongations inward for the support and protection of the different lobes of the brain. These projections also form sinuses that return the blood from the brain, and sheaths for the nerves that pass out of the skull. It may be called the protective membrane.

THE ARACHNOID is a delicate serous membrane which is placed between the dura mater and the pia mater. With the exception of the longitudinal fissure, it passes over the various eminences and depressions on the surface of the brain and does not dip down into them like the pia mater. Between the arachnoid and the pia mater is a space called the subarachnoid space in which is a certain amount of cerebrospinal fluid.

THE PIA MATER is a delicate membrane of connective tissue, containing an exceedingly abundant network of blood and lymph-vessels. It dips down into all the crevices and depressions of the brain, carrying the blood-vessels which go to every part. It may be called the vascular or nutritive membrane.

MENINGEAL SPACES AND CEREBROSPINAL FLUID.--The meningeal membranes and the spaces filled with fluid form a pad enclosing the brain and cord on all sides. Cerebrospinal fluid or lymph is formed in the brain ventricles from tufts of blood-vessels, and after filling the ventricles and the central canal of the cord escapes, through the thin roof of the fourth ventricles into the subarachnoid space. Consequently the fluid within the ventricles and surrounding the brain is in free communication with that within the central canal of the cord, and the spaces surrounding the cord. The cerebro-spinal fluid is a clear limpid fluid, having a salty taste, and a slightly alkaline reaction. It consists mainly of water (98.5%) with a small amount (1.5%) of animal and saline matters. It varies in quantity and is quickly secreted.

FUNCTION.--The cerebrospinal fluid serves as: (1) a nutritive medium for nerve cells just as lymph does for other cells of the body; (2) it is chemically protective tending to exclude such harmful substances as toxins; (3) it acts as a water-bed and thereby lessens chance of

injury to the brain and cord from the effects of blows or falls upon the head or neck; (4) it exerts a certain amount of pressure upon nerve tissue, which it is thought keeps the latter in a condition of tension that is favorable for its functioning.

REASONING is defined as the recall, comparison, analysis, and abstraction of definite memories in order to make a decision, such decision being known as a judgment. In order to reason one must concentrate. Concentration, reasoning, judgment and will power are abilities that demand effort, training and exercise for their development. Consequently, they do not develop as early in life as the emotion, i.e., love, hate, joy, fear, sympathy, etc. If the cerebrum is depressed by disease, drugs, or even fatigue, the higher powers are the first to be lost.

THE SPINAL CORD

The spinal cord is that portion of the nervous system lodged within the spinal canal of the vertebral column. It consists of a collection of gray and white substance, extending from the foramen magnum of the skull, where it is continuous with the medulla oblongata, to about the second lumbar vertebra, where it tapers off into a fine thread called the filum terminals. Before its termination it gives off a number of fibers which form a tail-like expansion, called the cauda equina. It diminishes slightly in size from the above downward, with the exception of presenting two enlargements in the cervical and lumbar regions, where the nerves are given off to the arms and legs respectively. It varies in length from sixteen to twenty inches (40 to 50 cm.), and except for the enlargements mentioned has an average diameter of one-half an inch (12.5 mm). The spinal cord is almost completely divided into lateral halves by a ventral and dorsal fissure; the ventral fissure dividing it in the middle line in front, and the dorsal fissure in the middle line behind. In consequence of the presence of these fissures, only a narrow bridge of the substance of the cord connects its two halves. This bridge, also called the isthmus, is traversed throughout its entire length by a minute central canal, which opens into the fourth ventricle at its upper end, and at its lower terminates blindly in the filum terminale.

MENINGES OR MEMBRANES.--The spinal cord does not fit closely into the spinal canal, as the brain does in the cranial cavity, but is, as it were, suspended within it. It is protected and nourished by three membranes which are continuous with the membranes covering the brain and are called by the same names, viz: (1) pia mater, (2) arachnoid, and (3) dura mater. Surrounding these three membranes are three spaces, called respectively (a) subarachnoid, (b) subdural, and (c) epidural.

(1) The PIA MATER closely invests the entire surface of the spinal cord. The subarachnoid space between it and the arachnoid membrane contains a small amount of cerebrospinal fluid.

(2) The ARACHNOID is a delicate serous membrane placed between the pia mater and the dura mater. The subdural space between these two membranes is very small and contains just enough cerebrospinal fluid to moisten their contiguous surfaces.

(3) The DURA MATER constitutes the outermost and thickest sheath. It does not serve as a periosteum for the vertebral bones, being separated from them by the epidural space which contains a certain quantity of areolar and adipose tissue and a network of veins.

FUNCTIONS OF THE SPINAL CORD.--

(a) It is an important center of reflex action.
(b) It consists of the principal conducting paths.
(c) Its centers act automatically. The activity of these centers is not as great as that of the respiratory, cardiac accelerator, and vasomotor centers in the medulla, but it is believed that stimuli arising as the result of some inherent property of the cord tissue are one source of the impulses that maintain the tonicity of muscle.

(d) It regulates the activity and nutritive condition of the tissues, and plays an important part in the production of body heat.

SPINAL NERVES

There are thirty-one pairs of spinal nerves, arranged in the following groups, and named for the region of the vertebral column from which they emerge:

Cervical	8 pairs
Thoracic	12 pairs
Lumbar	5 pairs
Sacral	5 pairs
Coccygeal.	1 pair

The first cervical nerve arises from the medulla oblongata and leaves the neural canal between the occipital bone and the atlas. With this one exception the spinal nerves spring from both sides of the spinal cord, and all except the coccygeal pass out through the intervertebral foramina. The coccygeal passes from the lower extremity of the canal.

MIXED NERVES.--The spinal nerves consist almost entirely of medullated nerve fibers, and are called mixed nerves because they contain both sensory and motor fibers.

The sensory nerves have their peripheral endings in receptors or sensory end-organs. These receptors receive stimuli, transform these stimuli to nerve impulses and pass them on to the nerves which carry them to centers in the central nervous system for interpretation or for linkage with motor nerves.

SENSE ORGANS.--A typical sense organ or sensory unit consists of (1) a peripheral end-organ or receptor which in most cases is constructed so as to be responsive only to a special form of stimulus, (2) connecting neurons whose only function is to conduct the nerve impulses originating in the end-organ, and (3) a center in the nervous system which interprets and determines the quality of the sensation. In this connection physiologists use the phrase specific nerve energy to designate the fact that each sense organ arouses its own specific quality of sensation, and no other. For example, the specific energy of the optic apparatus is visual sensation, and of the auditory apparatus is sound sensation. The view generally adopted is that this specificity is not due to the end-organs or conducting nerves, but to the center in the brain. It is through the agency of the sense organs that we derive information about ourselves, one another, and the world in which we live. The limitations of the sense organs restrict our knowledge of the many transformations of energy that are going on around us, except as we are able to devise means of extending them artificially. Thus our knowledge of the microscopic forms of life depends upon the extension of our sight by means of magnifying lens. Wireless waves circulated through the ether unknown to us until our sense of hearing was extended by the use of sound magnifying devices.

DEFINITION OF SENSATION.--Sensation is defined as perception through the sense organs and is the result of stimulation of these organs. The sensitiveness of the numerous receptors to stimulation varies; some respond to a very mild stimulus, e.g., in some parts of the body the slightest pressure will arouse a sensation while a similar degree of pressure in another part may fail to produce a sensation at all. The minimal stimulus necessary to arouse a sensation in any receptor is described as the threshold stimulus for that organ.

WHERE SENSATIONS ARE INTERPRETED.--Sensations are felt and interpreted in the brain. Our habit of projecting sensations to the part that is stimulated tends to obscure this fact. In reality we see and hear with our brains, because the eye and ear serve only as end-organs to receive the stimulus which must be carried to the brain and interpreted before we do see or hear.

CLASSIFICATION OF SENSATIONS

Sensations may be classified into two groups, i.e., special and common. The special senses are sight, hearing, touch, taste, and smell. All other sensations are grouped as common. Another classification is dependent on the part of the body to which the sensation is projected, and the two groups are named: (1) internal or interior senses and (2) external or exterior senses. These classifications have much in common, but differ slightly.

INTERNAL OR INTERIOR SENSES.--The internal senses are those in which the sensations are projected to the interior of the body. It is by means of these senses that we acquire a knowledge of the condition of our body. Among the interior senses we must include pain, the sensation from the semi-circular canals and vestibule of the internal ear, hunger, thirst, nausea, sexual sense, muscle sense, fatigue, and various obscure sensations which proceed from the viscera and give us the feeling of well-being or the reverse, also the desire for defecation and urination.

EXTERNAL OR EXTERIOR SENSES.--The external senses are those in which the sensations are projected to the exterior of the body. They form the means by which we become acquainted with the outside world. They include pressure and temperature sense (heat and cold), taste, smell, hearing and sight. Even this classification is not absolutely distinctive, as some sensations may be projected either to the interior or exterior of the body. Temperature and pain are examples of this class.